Bulletin of Marine Science

of the

Gulf and Caribbean

VOLUME 6, 1956
NUMBERS 1-4

Published by the University of Miami Press
ISSUED 1957 • CORAL GABLES, FLORIDA, U. S. A.

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OF THE GULF AND CARIBBEAN

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ML 15525

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BULLETIN OF MARINE SCIENCE
OF THE GULF AND CARIBBEAN

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THE GENUS *SCAPHANDER* IN THE GULF OF MEXICO AND NOTES ON THE WESTERN ATLANTIC SPECIES

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ABSTRACT

A summary of Gulf records for the genus *Scaphander* is presented with new records. Interspecific radula and gizzard relationships are briefly discussed and a key to the Western Atlantic species is given. The following are described as new: *S. loisae* and *S. watsoni rehderi.* The distribution of *S. watsoni* is given.

During the course of deep-water shrimp explorations in the Gulf of Mexico by the U.S. Fish and Wildlife Service M/V *Oregon* a small collection of *Scaphander* has been assembled. One of the species, *S. watsoni* Dall, has been found to be fairly common and the material is considered to contain a new subspecies. *S. nobilis* Verrill was found in one location. Several specimens of *S. clavus* Dall were caught in a restricted area east of the Mississippi Delta. Another species, formerly thought to be a paratype of *S. clavus,* is considered new.

It is recognized that mollusk sampling with a shrimp trawl leaves much to be desired and population estimates and distributional patterns based on shrimp trawl catches should be made with due reservation. (I have made several underwater observations, using self-contained diving gear, on the performance of shrimp trawls. In the Bahamas, 40-foot nets were seen passing over extensive beds of large *Strombus gigas* catching but a small fraction of those in the trawling path. On the other hand, many drags have been made where the ground line of the trawl digs into the bottom and the meshes of the net become clogged with mud and debris, permitting the retention of minute specimens. Most of the captures of *Scaphander* by the *Oregon* have been under these circumstances.)

The genus occupies a wide bathymetric range in both the Atlantic and Pacific Oceans, but deep-water collecting to date has revealed a scant distributional picture except for a few of the species. Live material of many species has been rarely collected, while other forms are known only from single or few shells found dead. Most of the material in several of the larger collections have no data indicating whether the specimen was found dead or alive, forcing undesirable speculation on the status of the species in the locality of capture. Water transport and the movement of shell by hermit crabs can present confusing patterns. That is, it is easy to recognize 200- and 300-fathom records of dead specimens of such species as *Neritina reclivata* and *Polynices duplicata,* which are found in these depths off Mobile and Pensacola, as not being significant distributional records (in the biology of the animal). But in dealing with those species characteristically found alive in deeper waters the relationship of dead shells to living populations and even aberrantly ranged individuals remains speculative.

Scaphander probably had its origin sometime during the Cretaceous (Gardner, p. 268), and at least three species are represented in the Tertiary fauna of the southeastern United States. Within the genus there are two groups of shell forms which are quite distinctive and form the subgenera *Scaphander* and *Bucconia.* The American status of *Sabatia* Bellardi described from the Pliocene is not clear. Dall (1889) first included it as a subgenus of *Scaphander* and described *bathymophila* as the first recent species. Later (1894) he described a second species from the Pacific, *Sabatia pustulosa.* Although I have not examined this second species, judging from both the description and figure given by Dall, it is almost certainly a *Scaphander.* Subsequently (1927) he returned *Sabatia* to full generic status.

None of these manipulations of *Sabatia* are explained, and only negative factors are presented for considering *bathymophila* a member of this genus. Since, as Dall states, *bathymophila* bears no special resemblance to the type species in shell shape, sculpture, proportions, callusing, and nothing is known of the soft parts; and since it does not appear to be closely allied with the known *Scaphander,* it would probably be well to consider this as a new and distinctive genus of the Scaphandridae. It is not included in the genus *Scaphander* in this paper.

Related in shape to the type species, *S. lignarius* L., are *S. gracilis* Watson, *S. punctostriatus* Mighels, *S. clavus* Dall, *S. loisae* new

species, and *S. watsoni* Dall in the Atlantic, and *S. interruptus* Dall and *S. pustulosa* Dall in the Pacific, and is represented in the Tertiary fauna of the southeast by *S. langdoni* Dall. This group is distinguished by the absence of the posterior pillar-like structure supporting an extension of the outer lip which characterizes the subgenus *Bucconia* Dall. *Bucconia* is represented in the Atlantic by two closely allied forms, *S. nobilis* and *S. stigmatica* Dall; in the Pacific by *S. mundus* Watson, *S. niveus* Watson, and *S. alatus* Dall; and in the Tertiary fauna by *S. grandis* Aldrich.

A combination of such shell characters as body proportions, shape of outer lip and body whorl, and form of spiral sculpturing separate most of the recent species. Punctate spiral striae are found on all members of the genus, and while differences in size and shape are not great, each species has its own characteristic patterns of punctations. Variations as can be found in northern and eastern Atlantic *S. punctostriatus* emphasize that it is not always reliable to differentiate on the basis of punctations alone.

As the shell increases in size additional striae are formed, first appearing as fine intercalary lines. In the case of *S. watsoni,* these usually develop to the proportions of adjoining striae within three-quarters of a whorl.

Fischer's figure (1887) of the radula of *S. lignarius* shows a definitive median tooth and he specifically states that the radula is tri-seriate. His figure also shows an apparent close attachment of the basal portions of opposing teeth. These two features differ from most subsequent references to this species and are not in agreement with any of the material of the other species. I have not examined *S. lignarius* but Cooke (1913) states that the genus is typically without central or marginal teeth, and this is definitely the case in *S. punctostriatus, S. nobilis,* and *S. watsoni* which I have dissected. The radula in these consists solely of paired laterals. Dall was in error when, in describing *Bucconia,* he claimed that " . . . the rachidian tooth (is) proportionately larger . . ." than in the typical species. It seems probable that this resulted from a comparison of Fischer's apparently erroneous figure with Verrill's figure of *S. nobilis* which could conceivably be misinterpreted.

Interspecific radular differences are minute, often barely discernible (see Fig. 1). All of the present material had been fixed and the amount of distortion in the positioning of the teeth due to extreme contraction is unknown. In situ, in this condition, the tips

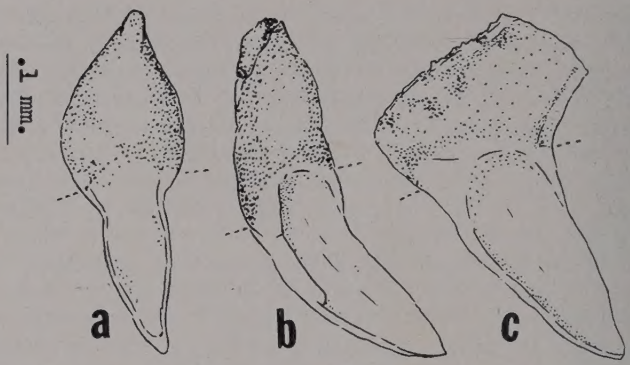

FIGURE 1. Individual lateral teeth of three species of *Scaphander.* a - *S. watsoni rehderi,* b - *S. nobilis,* c - *S. punctostriatus.*

of the teeth on one side are slightly offset from those on the other, so that when drawn together they form an arch. Anteriorly they are in a more or less upright position with the tips curving mesially, posteriorly closing, zipper-like, with the exposed portion of the teeth intermeshing to a much greater degree than is shown by Verrill. The exposed portion of each tooth is rounded with a hollowed inner surface. This interesting structure with the absence of both abrasive and offensive characteristics suggests a grasping type function.

The lateral gizzard plates show considerable intraspecific variation in shape. The rounded-quadrate shape shown by Verrill for *S. nobilis* is not always characteristic, and varies to a more triangulate form. Presumably Dall also used Verrill's figure for his description of the gizzard plates of *Bucconia.* In *S. watsoni* and *S. punctostriatus* the lateral plates are more uniformly triangular.

The food of *Scaphander* appears to be made up chiefly of minute shelled animals which are picked up whole and held in the crop, finally being ground between the gizzard plates. The crops of all but one of the *S. watsoni* examined contained only forams and mud. The other contained two pieces of scaphopod shell. Crops of *S. nobilis* and *S. punctostriatus* contained scaphopods, forams, and mud. European *Scaphander* (presumably *lignarius*) have been observed swallowing *Dentalium* whole (Cooke).

A Provisional Key to the Genus Scaphander in the Western North Atlantic

a. Shell with a posterior pillar supporting an extension of the outer lip (subgenus *Bucconia*).
   b. Maximum width of body whorl less than two in total length. *Sabatia*? *bathymophila* Dall
   bb. Maximum width of body whorl more than two in total length.
      c. Shell with heavily punctate spiral lines, punctations as wide or wider than intervening spaces between spirals, outer profile of body whorl sigmoid. *Scaphander stigmatica* Dall
      cc. Shell with delicate rectangular punctations, much narrower than spaces between spirals. Outer profile of body whorl smoothly rounded. *Scaphander nobilis* Verrill

aa. Shell without a posterior pillar. Lip may or may not extend beyond apex but is broadly rounded and directly joins the body (subgenus *Scaphander*).
   b. Apex a minute pit, outer lip not forming a prominent carina.
      c. Shell large and thin, total length reaching 35 mm or more. Punctations typically spirally elongate, their width less than one-quarter their length, usually fine, elongate lines, rarely fusing to form continuous grooves. Posterior extension of outer lip (when present) thin and fragile. *Scaphander punctostriatus* Mighels
      cc. Shell small and heavy, probably not exceeding 20 mm. Striae crowded, made up of joining oval punctations which form strong grooves. Posterior edge of outer lip heavy and strong. *Scaphander loisae* new species
   bb. Apex a depressed hollow, surrounded by a carina formed by the outer lip joining the body.
      c. Maximum width of shell more than 60 percent of maximum length. Punctations distinct. A heavy callus on the parietal wall, extending into and mostly filling the hollowed apex. *Scaphander clavus* Dall
      cc. Maximum width less than 60 percent of maximum length. Punctations joining to form scalloped-edge striae.
         d. Maximum width about 48 to 53 percent of length in

specimens over 15 mm. Periostracum light lemon yellow. Dorsal accessory gizzard plate with a slightly hollowed outer surface.

Scaphander watsoni watsoni Dall

dd. Maximum width about 53 to 57 percent of length in specimens over 15 mm. Periostracum mahogany brown. Dorsal accessory gizzard plate with outer edges pinched together lengthwise.

Scaphander watsoni rehderi new subspecies

Scaphander (*Bucconia*) *nobilis* Verrill

Figure 2. A—B

S. nobilis Verrill, 1884, p. 209.

One *Oregon* record from station 1303, 28°47′ north latitude, 87° 50′ west longitude, depth 1150-1200 fathoms. Four specimens, three alive, were taken in this haul. This is apparently the first record for this species from the Gulf of Mexico. Dall's record (1889) from the gulf was subsequently changed (1927, p. 26) to *S. stigmatica* from south of Cuba.

The gulf material shows some deviation from *S. nobilis* off Delaware Bay and Georges Bank. The punctations of the striae are more numerous and heavier, more closely spaced. The number of spiral lines varies from 120 to 136 for specimens of 24.8 to 30.8 mm. Seven specimens from three localities along the northeast coast vary from 81 to 122 spirals within a size range of 25.0 to 36.3 mm. The gulf specimens are much more fragile and show greater variation in shape. One of the four is more elongate and another is more inflated than any of the east coast shells. Radulae are identical.

Scaphander (*Bucconia*) *stigmatica* Dall

Figure 2. D—E

S. stigmatica Dall, 1927, p. 26.

This West Indian species has not been found in the gulf, although it should not be unexpected. It is known only from the type (U.S.-N.M. 9596); a dead specimen taken at U. S. B. F. station 2127, in 1,639 fathoms south of Cuba.

In shape it is very close to *S. nobilis*. It differs chiefly in the form of the punctations which are much larger and more closely spaced. However, a *S. nobilis* from 1,544 fathoms southwest of Nantucket (U.S.N.M. 78614) shows very similar sculpturing.

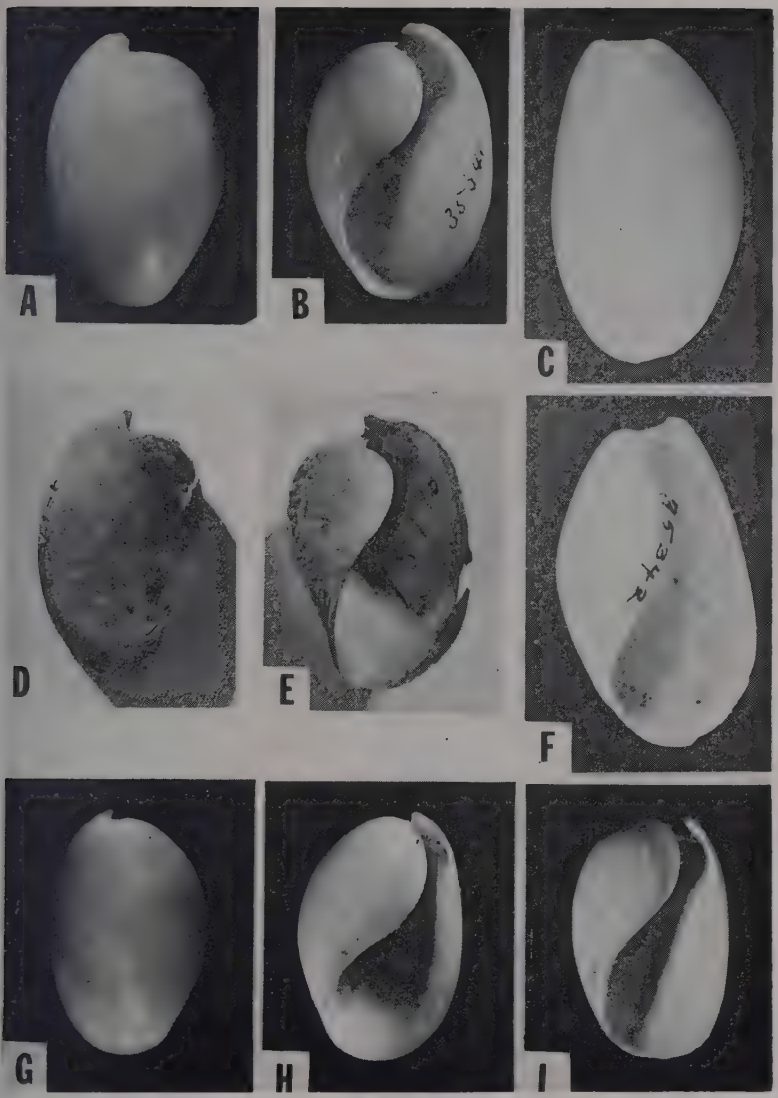

FIGURE 2. A - B, *Scaphander nobilis,* type, 37.2 mm; C and F, *S. punctostriatus,* 38.0 mm; D - E, *S. stigmatica,* type, 39.1 mm; G - H, *S. loisae,* type, 17.8 mm; I, *S. clavus,* type, 17.0 mm; (Photographs A, B, D, E, G, H, courtesy of the U.S. National Museum. Photograph I, courtesy of the Museum of Comparative Zoology.)

Scaphander (*Scaphander*) *loisae* new species
Figure 2. G—H

Scaphander punctostriatus var. *clavus?* Dall, 1889b, p. 52.

Holotype. Maximum length, 17.8 mm, maximum width, 12.1 mm. Dead specimen but in perfect condition. Color white, with a thin, transparent periostracum. Parietal wall strongly flexed, covered with a thin, white callus. Apex a minute pit. Outer lip moderately curved with a prominent posterior extension. Aperture moderately expanded anteriorly, very narrow posteriorly. Approximately 145 crowded, punctate spiral grooves, varying greatly in width. U.S.N.M. 95188. *Blake* station 281, 288 fathoms off Barbados.

Discussion. Dall lists the collection of one specimen each of *S. punctostriatus* from two localities, off Barbados and in the Gulf of Mexico. He considered these a possible subspecies (variety), and designated the gulf specimen as the type (M.C.Z. 6981) of *S. punctostriatus clavus.* Actually, the two specimens are distinct. The type and a fairly large series of *S. clavus* from the Oregon collections (although most are in poor condition) show several consistent differences from the Barbados specimen.

The minute apical pit of *S. loisae* immediately distinguishes it from the *S. clavus* which has a broad apical depression generally filled with a heavy callus. Also, the spiral grooves of the former species differ markedly from the squarish or rectangular and usually distinct punctations of *S. clavus.*

It differs from *S. punctostriatus* in having continuous grooves compared to the typically fine, elongate punctations. It is also considerably heavier than any *S. punctostriatus* of similar length.

Known only from the type.

Scaphander (*Scaphander*) *clavus* Dall
Figure 2. I

S. punctostriatus var. *clavus?* Dall, 1889b, p. 52.

Dall's description of this species is altogether too meager for diagnostic purposes. The 17mm type (M.C.Z. 6981) from off the Mississippi Delta, Blake station 48, 28°47′30″ north latitude, 88° 41′30″ west longitude, in 533 fathoms appears to have been collected dead. No living specimens are known. A description of the largest and most perfect specimen of the *Oregon* material (U.S.N.M. 609-952) is as follows:

Length 25.3 mm, maximum width 16.6 mm, maximum height of aperture 25.5 mm. Dead specimen, shell eroded and chalky.

Color white, with no trace of periostracum remaining. Parietal wall moderately flexed, covered with a heavy callus which is 1.1 mm thick in the center, the elevation from the parietal wall forming a modified keel-like structure. The callus extends posteriorly to and partially covers the sunken apex. Apex surrounded by a low keel formed by the posterior edge of the outer lip. Profile of the outer lip flattened, almost forming a straight line in the center. General shape stubby, with little posterior attenuation. Spiral sculpturing badly eroded but showing approximately 84 punctate striae. Striae inequidistant and punctations variable in size. However, within each spiral the punctations are almost identical. Shape of the punctations generally rectangular or square, rounded in varying degrees at the corners. Locality, *Oregon* station 1107, position 29°03′ north latitude, 88°25′ west longitude in 210-235 fathoms.

Several characters unequivocally validate this species. *S. punctostriatus* (Fig. 2, C and F) reaches a much greater size, and the typical form of the punctations are fine elongate widely spaced slits compared to the heavy rectangular to squarish form in *S. clavus*.

S. punctostriatus, even in the adult stage, has a thinner and more fragile shell than *S. clavus* of half the size. The proportionately much larger body whorl, less posterior attenuation, and the development of the heavy callus on even the young forms also serve to distinguish this species.

All of the present material was dead, enveloped in sagartiid anemones which in turn formed carcinoecia for the hermit crab *Sympagurus pictus* Smith (identified by Dr. Fenner A. Chace, U.S.N.M.). The spiral chamber within the anemone occupied by the crab forms a continuous tube tapering into the aperture of the shell. (Several other species of gastropods are commonly found incarcerated in these anemones.) These specimens range in size from 15.1 to 26.1 mm, and were found at several localities on the continental slope in the northern gulf between 88° and 88°33′ west longitude in depths of 195 to 300 fathoms.

S. clavus is distinguishable from all other recent members of the genus in the shape of the shell. The profile is almost identical to *Bulla occidentalis* A. Adams except for being slightly flattened posteriorly.

Scaphander (*Scaphander*) *watsoni watsoni* Dall
Figure 3. C and D (Lower row)

Scaphander? watsoni Dall, 1881, pp. 99-100.
Scaphander watsoni Dall, 1889b, pp. 52-53.

This species was unfortunately described from a juvenile specimen scarcely one quarter the size of the average adult, and as a result much additional work is needed to definitely ascertain the status and relationships between the several groups of larger specimens that have been subsequently referred to as *S. watsoni*. The young stages (under 15 mm) show an almost bewildering variation in shell characters. Two specimens in the collection of the Museum of Comparative Zoology which were identified by Dall from the *Blake* collections best illustrate this by the following comparison to the type:

	Type	MCZ 6985	MCZ 6986
Maximum length in mm	8.75	8.3	8.5
Percent maximum width of body whorl in length	29	35	39
Percent maximum width of shell in length	49	60	49
Percent maximum width of aperture in length	37	48	47
Number of spiral threads per mm of length (average)	2.8	8.2	3.6

These two shells came from off Bahia Honda, Cuba (6985) in 200 fathoms, and from 84 fathoms on the Campeche Bank (6986). The extensive series of small *S. watsoni* collected by Henderson, now in the U. S. National Museum, four specimens in the collection of the University of Miami Marine Laboratory ranging in size from 4.5 to 14.9 mm from off Miami and the Florida Keys, several specimens in private collections, and material in this size range from the Campeche Banks and northeastern gulf show equal variation.

Dall (1881, p. 100) described the spiral sculpturing of the type specimen as ". . . . . consisting of some twenty-five sharp, strong, channeled, clear-cut grooves, not punctate or in any way irregular, except that they are more crowded near the summit than elsewhere. . . . . ". Later (1889b, p. 53) he identified two additional lots of S. *watsoni* from 324 fathoms in the northern gulf without comment on the sculpturing. These specimens and material from

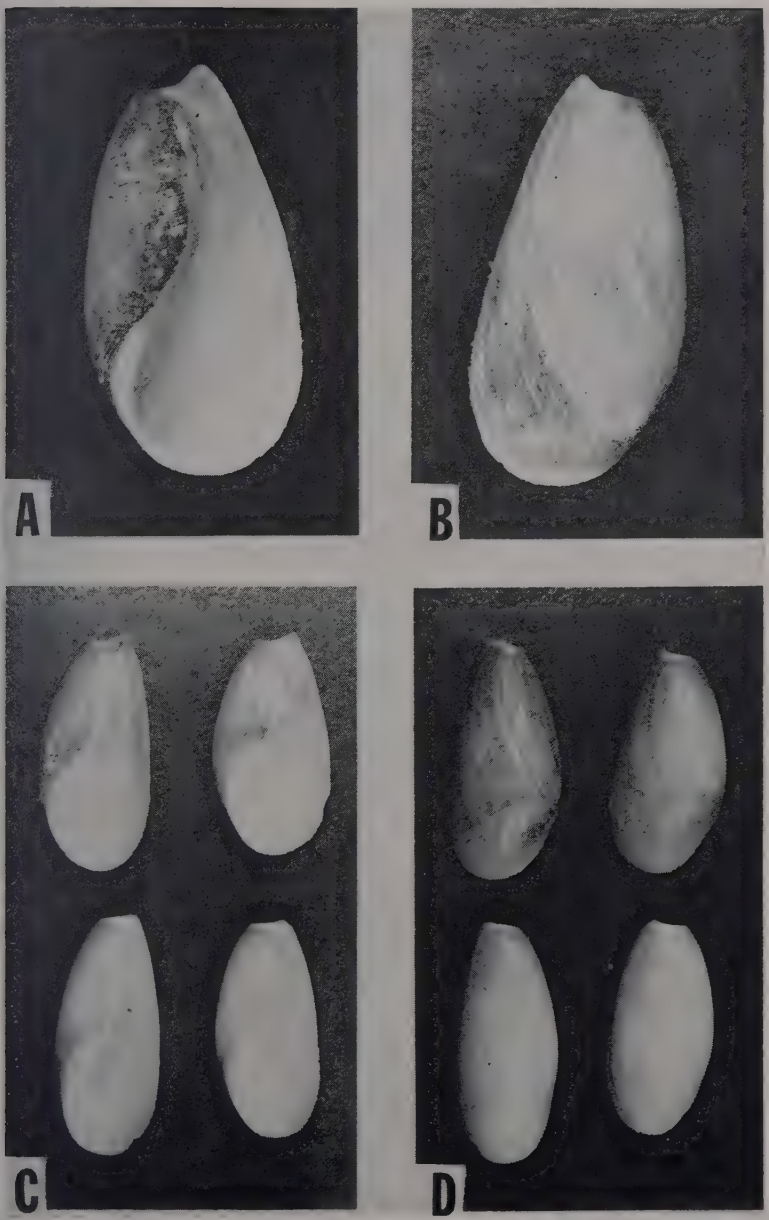

FIGURE 3. A - B, *Scaphander watsoni rehderi*, type, 39.3 mm; C - D. dorsal and ventral views of *S. watsoni watsoni* (lower row) and *S. watsoni rehderi* (upper row), 25 to 30 mm.

this area collected by the *Oregon* as well as the previously mentioned material in other collections, all show fine and delicate but readily distinguishable punctations within the spirals. In most cases the spirals appear to be made up of connecting or closely "overlapping" punctations with the edges of the grooves showing a corresponding scalloped effect if viewed under a microscope. Only the terminal few millemeters of the central and anterior striae of adult specimens show an absence of the punctate feature.

As best as can be determined, all of the available material under 26 mm in length referable to *S. watsoni* was collected *dead*. This includes the very extensive series totaling hundreds of specimens in the U. S. National Museum from numerous localities along the southeastern Florida coast. McGinty (1955, p. 83) records adults from this same area as reaching about 17 or 18 mm in length, but he doesn't indicate if *any* have ever been taken alive. In view of some of the present conclusions, examination of the soft parts of such material would be interesting. However, even if live *S. watsoni* has been found in that area it remains questionable whether 18 mm specimens are adults or even indicate the existence of adult populations. During deep water trawling by the *Oregon* in the western approaches to the Straits of Florida, dead shells ranging up to 26 mm in length were picked up and specimens up to 27.4 mm have been collected in the deep water along the north coast of Cuba. A general picture of the distribution of this species by shell size shows the largest specimens in the Gulf of Mexico and approaches, and along the Cuban coast; then, dead shells of slightly smaller individuals in the western Straits area, specimens up to 18 mm along the southeast and central Florida coasts; and lastly, a diffusion of minute shells as far north as Hatteras. This pattern may have been brought about by either water transport of dead shell with primary consideration being given to the direct influence of the Gulf Stream, or the northward transportation of planktonic larvae and unsuccessful establishment along the way.

A series of nine living specimens of *S. watsoni* ranging from 26.0 to 31.6 mm in length was collected at *Oregon* station 489 in 254 fathoms off Tampa. Scattered dead shells in this size range have been brought up in the trawl drags made in depths of 200 to 300 fathoms from west of Cape San Blas to Key West. These compared perfectly in all shell characters to the series in the Museo Poey which range from 18.7 to 27.4 mm and were collected at eleven deep-water locali-

ties around Cuba. The few characters given by McGinty for *S. pilsbryi* (p. 82) strongly suggest that his specimen is *watsoni*. Without any information on the internal features, the "light straw" colored periostracum, proportionate width of shell (see Fig. 4), general shape, and size all correlate well with the continuous series of *S. watsoni* shells that extend along continental slope of the eastern gulf from Pensacola to Key West, and across the Straits to Cuba.

The clarification of the status of *S. pilsbryi* is important in that a comparison of the shells and certain internal features of material that has been collected living from two different areas in the gulf reveals a consistent variation that should substantiate subspecific ranking.

Scaphander (*Scaphander*) *watsoni rehderi* new subspecies
Figure 3. A—B, C—D (upper row)

S. watsoni Dall, 1889b, pp. 52-53.

Holotype. Length of shell, 39.3 mm, maximum length including posterior extension of outer lip, 41.0 mm, maximum width of body whorl, 11.5 mm, maximum width of shell, 21.4 mm, maximum width of aperture, 16.7 mm. Color white, with a faint buff stain over most of the shell. Periostracum dark yellowish to mahogany brown. Apex open, surrounded by a prominent ridge formed by the outer lip joining the body. A thin, white callus on the parietal wall extends into but does not cover the apical depression. The outer lip shows a noticeable central convexity in direct profile. Approximately 85 spiral, scalloped-edged grooves, including the more prominent intercalary lines. U.S.N.M. 609948. *Oregon* station 1282, 29°10′ north latitude, 88°03′ west longitude, 260 fathoms, grey mud, bottom temperature 50.4°F.

Discussion. Dall's reference to the large specimens from the Gulf of Mexico (U.S.N.M. 95187) are this subspecies. Only specimens of approximately 15 mm or larger can be distinguished from the typical species with any degree of certainty on the basis of shell characters alone. Paratypes from 12 localities between 88°25′ and 88°33′ west longitude in depths of 195 to 300 fathoms varied in width from 53 to 57 percent of length compared to a variation of 48 to 53 percent for the typical species from off Tampa and Cuba. This slightly greater proportionate width shows up mainly as a more expanded aperture anteriorly giving the shell a pear-like shape rather than the typical elongate-oval form (see Fig. 3. C-D). *S. watsoni rehderi* as a group also averages slightly more striae per millimeter of length in specimens

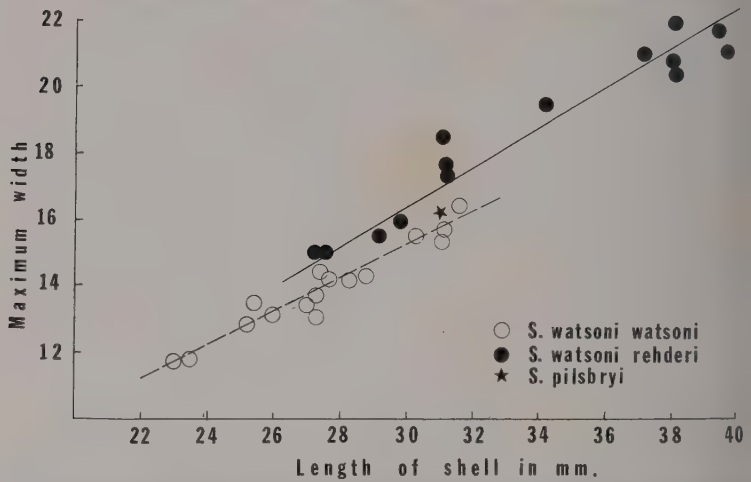

FIGURE 4. Relations between shell length (altitude) and maximum width in two subspecies of *Scaphander*. Solid line is linear regression for *S. watsoni rehderi*. Broken line is linear regression for *S. watsoni watsoni*.

of 25 mm or larger but this character completely intergrades. There is no discernible difference in the radulae of the two subspecies, and the lateral gizzard plates are indistinguishable. However, the dorsal accessory gizzard plate of *S. watsoni rehderi* shows the unique feature of having the dorsal edge pinched together for most of their length, compared to the open trough-like surface of *S. watsoni watsoni* (see Fig. 5) and all other species. Teleologically speaking, this may be explained as an ecological feature where the average size of the shelled organisms that comprise the basic diet of *Scaphander* are larger causing a consistently wider expansion of the lateral plates, the postero-dorsal edges of which work against the dorsal edges of the dorsal accessory plate. I have no data to substantiate this beyond noting the larger average size of forams in the crops of *S. watsoni rehderi* than in the few individuals of other species I have examined. For the present this character readily separates the two forms. The new subspecies is named for Dr. Harold A. Rehder of the U. S. National Museum.

The restricted areas in the gulf from which both subspecies have been found living cause some question to be raised on the range of the species as is indicated by the capture of dead shells. Of 140 trawl-

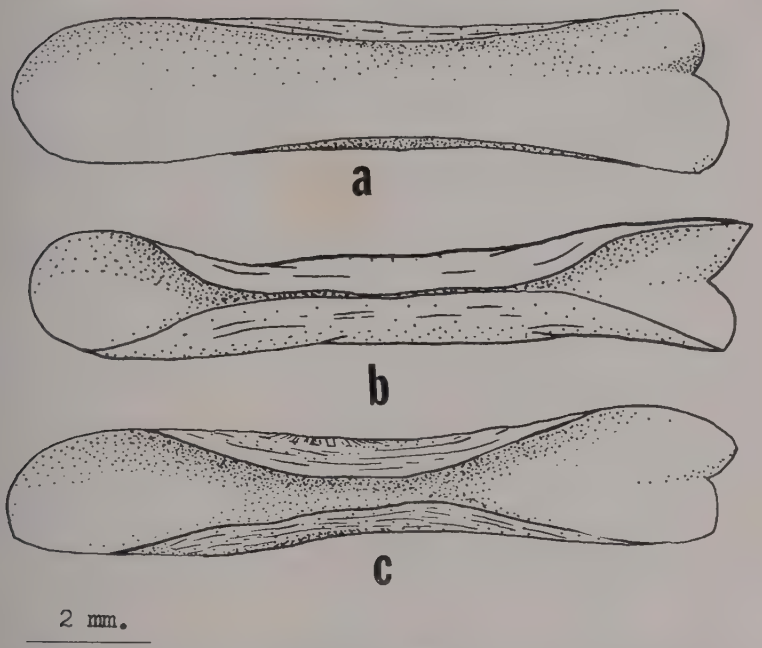

FIGURE 5. Outer aspect of dorsal accessory gizzard plates of *Scaphander watsoni watsoni* (a), and *S. watsoni rehderi* (b and c).

ing stations made along the northern gulf coast between 85° and 89° west longitude in depths of 100 to 500 fathoms, living *rehderi* were found only within the previously mentioned 8-mile longitudinal band in depths of 200 to 280 fathoms. Empty shells were fairly common throughout this range. Living *S. watsoni watsoni* were taken at a single locality. Eighty drags made in this depth range in other areas of the gulf, as well as almost 800 drags inside of the 100-fathom curve, revealed no evidence of the presence of living *S. watsoni* and no adult shells have been found in these other areas. Even considering the relative inefficiency of shrimp trawls as collecting gear for mollusks these records indicate a much greater restriction of living populations than is shown by the diffusion of small *S. watsoni* shells which could be attributed to water transport (although some of the distances seem remarkable), or the unsuccessful establishment of planktonic larvae (although the larvae are unknown).

Acknowledgments

Considerable assistance was given in the preparation of this paper. I am especially grateful to Dr. Harold A. Rehder of the U. S. National Museum for his suggestions, loan of specimens, and photographs of the types of *S. nobilis, S. stigmatica,* and *S. loisae;* to Dr. William J. Clench of the Museum of Comparative Zoology for the loan of specimens and the photograph of the type *S. clavus;* and to Dr. Carlos Aguayo of the Museo Poey; Mr. Gilbert L. Voss of the Universiy of Miami Marine Laboratory, and Mr. and Mrs. Larry Townsend of Miami, Florida for the loan of specimens.

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DEFINITIONS AND METHODS OF MEASURING AND COUNTING IN THE BILLFISHES (ISTIOPHORIDAE, XIPHIIDAE)[1]

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ABSTRACT

The need for definition and standardization of methods of measuring and counting in ichthyology is discussed, with special reference to billfishes. A series of measurements and counts for the latter group is proposed and methods and definitions for each are given. The body length is discussed in more detail in connection with its importance as a base length and attention is called to the need for dissection in order to ascertain accurately the number of spines in the first dorsal and first anal fins.

INTRODUCTION

The need for accurate definition and standardization in the use of biometric and meristic characters in systematic ichthyology has long been recognized (Ricker and Merriman, 1945). It is obvious that with the exception of truly self-explanatory characters, most measurements and counts must be defined in order to enable other workers to interpret the data. The need for standardization arises from the fact that in most cases, different methods (as applied to a given group), no matter how well defined, cannot be equalized for comparative purposes.

Owing to the high precision required, lack of definition and standardization of methods becomes quite a problem in the study of closely related species or infraspecific categories, and especially in the biometric analysis of populations where several independent workers using different methods may be working on the same group. Furthermore, the marked differences in structure existing among certain families of fishes usually prevent the application of a method to groups other than the one for which it was designed.

In recent years, the increasing interest in the biometric analysis of populations of tunas by various independent workers, has brought about the necessity to define and standardize the methods used in measuring and counting. The various methods which have been proposed are essentially in agreement (Godsil and Byers, 1944:125-129; Marr and Schaefer, 1949; Rivas, 1955) and have been successfully adopted by practically all workers in the field.

[1]Contribution No. 149 from the Marine Laboratory, University of Miami. This constitutes a technical report to the Charles F. Johnson Foundation.

Also recently, new interest has developed in the taxonomy and population analysis of the sailfishes, spearfishes, marlins (Istiophoridae) and broadbill swordfish (Xiphiidae), a most confused group collectively known as "billfishes."

As far as can be ascertained, no formal methods of measuring and counting have ever been proposed for the billfishes. A survey of the literature shows that most of the methods used vary among the different workers and that lack of definitions renders the measurements and counts difficult or impossible to interpret. In addition, certain methods of measuring and counting employed in the past appear to be unsatisfactory and have resulted in questionable taxonomic interpretations.

For reasons already indicated above, the methods employed in the tunas cannot be applied to the billfishes. It is the purpose of the present paper to propose a series of measurements and counts for the latter group, based on previous field and laboratory experience as a result of studies conducted under sponsorship of the Charles F. Johnson Foundation. New characters not previously used in connection with billfishes are also included.

All the measurements described (excepting body girth) are straight-line distances and are made in metric units to the nearest millimeter, with slide calipers or dividers according to the size of the fish and the distance to be measured. (See also Godsil and Byers, 1944:125, and Marr and Schaefer, 1949:241, 242). In large fish, long measurements beyond the range encompassed by the larger calipers may be made with a steel tape graduated in metric units. For this purpose sliding metal or wooden arms similar to those used in the calipers should be attached to the tape, taking care that the tape remains straight during the measurement, with the arms perpendicular to it. As already pointed out by Morrow (1952:53,54), measurements taken with a tape alone are not satisfactory, since a straight line distance can seldom be obtained.

Also, in order to avoid error in the longitudinal measurements, the axis of the body should be maintained as straight as possible. This may be accomplished by placing the specimen on a flat surface and properly propping up the head, the caudal peduncle and the caudal fin. Although it is conventional in ichthyology to use the left side of the fish for the lateral measurements, the best, or either side should be selected, according to the condition of the part to be measured. The jaws should be tied closed, especially in connection with measure-

ments involving the tip of the mandible as a point of reference.

The numbers in the text for each measurement correspond to the numbers in the figure.

Measurements

1.—*Body length.*—A survey of the literature shows a great deal of inconsistency as to the selection of a body length in billfishes and lack of definition whereby the points of reference of this measurement can be accurately established. With very few exceptions, the instrument employed is not mentioned and there is no statement as to whether or not the measurement follows the curvature of the body (tape) or constitutes a straight-line distance (calipers or dividers).

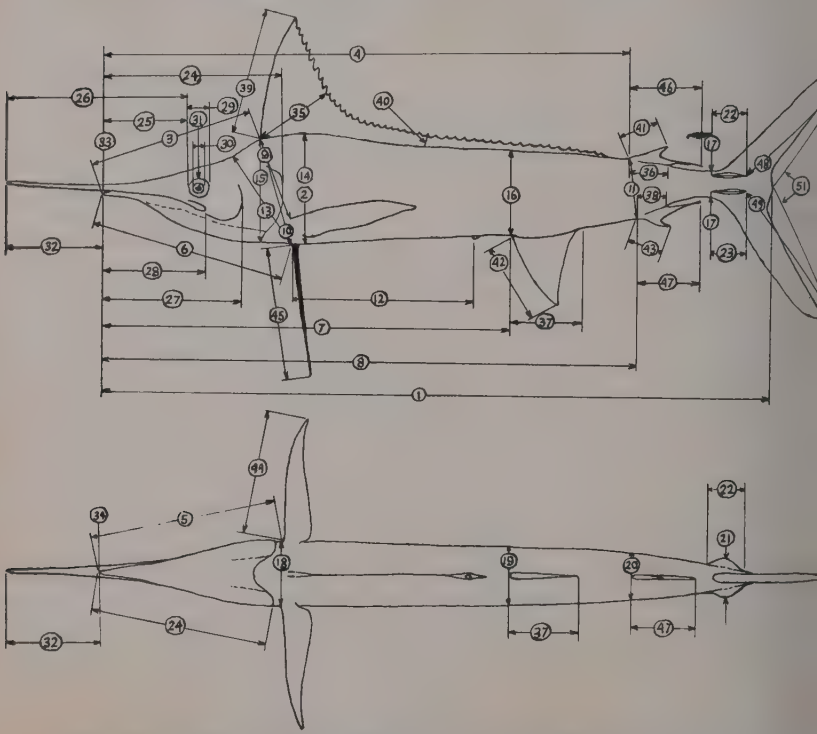

Figure 1. Lateral and ventral views of a marlin, showing location of measurements. The numbers correspond to the numbers in the text.

It must be emphasized that since most, or all, other (relative) body measurements are referred to the body length as a base length, regardless of the method used in expressing proportions (ratios, regressions, etc.), this character must be defined with great care. It is obvious that if the base length is in error, all body proportions will also be in error regardless of how accurately the body parts may have been measured.

The "standard length" or "body length" for billfishes as used by most workers in the past does not seem to be satisfactory for various reasons. There has been agreement in the selection of the anterior endpoint (tip of bill) but the posterior end point is variously interpreted as ". . . tail base" or ". . . mid-point of the peduncle . . ." (Conrad and LaMonte, 1937, table 1 and p. 209); or ". . . the midpoint of the shallowest vertical diameter of the caudal peduncle," (Gregory and Conrad, 1939:444), etc. Other workers offer no definitions or simply refer to "standard length" (deBuen, 1950:171) without further comment.

Despite lack of absolute standardization (Ricker and Merriman, 1945), most ichthyologists agree in that "standard length" is the straight line measurement taken between the tip of the snout and the middle of the caudal base, where the middle caudal ray joins the last (hypural) vertebra. In the billfishes, however, the middle of the caudal base cannot be determined without involved dissection, and the structure of the hypural vertebra and the caudal fin do not permit the determination of an accurate point of reference. Even after performing dissection, the point cannot be estimated from external form. For obvious reasons, the middle point on the posterior margin of the middle caudal rays (crotch of tail) constitutes a much better point of reference from the point of view of accuracy and convenience. In addition, the median caudal rays in billfishes are well protected by the upper and lower lobes of the fin, and are very seldom damaged.

As to the anterior point of reference, the tip, or a considerable portion of the distal end of the bill is frequently broken off, or the bill itself may be malformed and not attain its true length. For this reason, many otherwise valuable specimens have to be discarded or an inaccurate body length will result if the tip of the bill is used for the anterior point of reference. The mandible, on the other hand, is well protected by the bill and its tip is very seldom broken off or malformed.

In the light of the above discussion, it is therefore proposed that the body length in billfishes be measured between the tip of the mandi-

ble (with the jaws closed) and the middle point on the posterior margin of the middle caudal rays.

2.—*Body girth.*—Measured with a tape on one side of the body following its curvature from the uppermost point on the edge of the dorsal groove, vertically to the edge of the pelvic groove (midline of belly in the swordfish); the resulting figure is then multiplied by two. This character, when expressed as a proportion of the base length, serves as a good indicator of the degree of robustness of the body.

3.—*First predorsal length.*—Measured from the tip of the mandible to the origin of the first dorsal fin. The latter point is the intersection of the anterior margin of the fin with the contour of the back when the fin is held erect.

4.—*Second predorsal length.*—Measured from the tip of the mandible to the origin (as defined above) of the second dorsal fin. The origin of the second dorsal is not as clearly defined as that of the first, and the point must be estimated as accurately as possible. Since this is a long measurement, the error, if any, is negligible.

5.—*Prepectoral length.*—Measured from the tip of the mandible to the origin of the pectoral fin. The origin of the pectoral fin is the intersection of its anterior basal margin with the side of the body, when the fin is held erect.

6.—*Prepelvic length.*—Measured from the tip of the mandible to the origin of the pelvic fin. The latter point is the intersection of the anterior basal margin of the pelvic fin with the belly when the fin is held erect.

7.—*First preanal length.*—Measured from the tip of the mandible to the origin of the first anal fin. The latter point is determined in the same manner as the origin of the first dorsal fin (See above).

8.—*Second preanal length.*—Measured from the tip of the mandible to the origin of the second anal fin. The latter point is determined in the same manner as the origin of the second dorsal fin (See above).

9.—*Origin of first dorsal to origin of pectoral.*—This character is self-explanatory according to descriptions of these fin origins as given above (See first predorsal length and prepectoral length).

10.—*Origin of first dorsal to origin of pelvic.*—This character is self-explanatory according to descriptions of these fin origins as given above (See first predorsal length and prepelvic length). It constitutes a good indicator of the anterior depth of the body.

11.—*Origin of second dorsal to origin of second anal.*—This character is self-explanatory according to descriptions of these fin origins

as given above (See second predorsal length and second preanal length). It constitutes a good indicator of the posterior depth of the body.

12.—*Origin of pelvic to vent.*—Measured from the origin of the pelvic fin (See prepelvic length) to the anterior border of the anus.

13.—*Origin of pelvic to nape.*—Measured from the origin of the pelvic fin (See prepelvic length) to the nearest point on the midline of the nape. This character gives good quantitative expression of the "hump" associated with ontogenetic stages of certain species.

14.—*Greatest depth of body.*—This character is self-explanatory. Its points of reference correspond with those for body girth as described above.

15.—*Depth of body at origin of first dorsal.*—Measured from the origin of the first dorsal (See first predorsal length), vertically to the midline of the isthmus, not including the branchiostegal membrane if it extends to the latter point. This character is a good indicator of the posterior depth of the head and may be used in connection with origin of pelvic to nape, to obtain a quantitative interpretation of the magnitude of the "hump."

16.—*Depth of body at origin of first anal.*—Measured from the origin of the first anal fin (See first preanal length), vertically to the edge of the dorsal groove. This character is a good indicator of the middle depth of the body.

17.—*Least depth of caudal peduncle.*—Measured at the precaudal transverse grooves.

18.—*Width of body at origin of pectorals.*—Measured between the origins of both pectoral fins (See prepectoral length). This character is a good indicator of the anterior width of the body and may be more accurately and conveniently obtained with the fish hanging by the tail.

19.—*Width of body at origin of first anal.*—Measured at the widest point on the vertical from the origin of the first anal fin. This character is a good indicator of the middle width of the body and may be more accurately and conveniently obtained with the fish hanging from the tail.

20.—*Width of body at origin of second anal.*—Measured according to the same procedure described for the above character. This character is a good indicator of the posterior width of the body.

21.—*Width of caudal peduncle at keel.*—Measured between the outermost point on the edge of each caudal keel (swordfish). Upper caudal keels in sailfish, spearfish and marlin.

22.—*Length of upper caudal keel.*—Measured between the points where the keel merges with the caudal peduncle anteriorly and with the caudal fin posteriorly. These points, although not well defined, may be estimated fairly accurately. Same procedure for single keel of swordfish.

23.—*Length of lower caudal keel.*—Measured according to the same procedure described above for the upper caudal keel.

24.—*Head length.*—Measured from the tip of the mandible to the most distant point on the margin of the opercle.

25.—*Snout length.*—Measured from the tip of the mandible to the most anterior point on the fleshy margin of the orbit.

26.—*Bill length.*—Measured from its tip to the most anterior point on the fleshy margin of the orbit.

27.—*Preopercular length.*—Measured from the tip of the mandible to the most distant point on the margin of the preopercle.

28.—*Maxillary length.*—Measured from the tip of mandible to the posterior end of the maxillary.

29.—*Orbit diameter.*—Measured as a horizontal distance from the most anterior point on the fleshy margin of the orbit.

30.—*Iris diameter.*—Measured as a horizontal distance from the most anterior point on the margin of the (ossified) sclera.

31.—*Interorbital width.*—Measured as the shortest distance between the uppermost point on the fleshy margin of the orbits.

32.—*Tip of mandible to tip of bill.*—This character is self-explanatory. Care must be taken that the jaws are well closed.

33.—*Depth of bill.*—Measured on the vertical passing through the tip of the mandible.

34.—*Width of bill.*—Measured on the vertical passing through the tip of the mandible.

35.—*Origin of first dorsal to edge of fin.*—Measured from the origin of the first dorsal fin (See first predorsal length) to the nearest tip (on dorsal edge) of a dorsal spine. This measurement is connection with the anterior height of the fin (see below) gives a good quantitative interpretation of the magnitude of the anterior dorsal lobe.

36.—*Length of second dorsal base.*—Measured from the origin of the second dorsal fin (See second predorsal length) to the end of the fin base. The latter point is the intersection of the posterior basal margin of the last ray with the back.

37.—*Length of first anal base.*—Measured from the origin of the

first anal fin (See first preanal length) to the end of the anal groove. To the last (very short) discernible spine in the swordfish.

38.—*Length of second anal base.*—Measured according to the same procedure described above for the length of the second dorsal base.

39.—*Anterior height of first dorsal.*—Measured from the origin of the first dorsal fin (See first predorsal length) to the tip of the lobe.

40.—*Length of middle dorsal spine.*—The 25th dorsal spine measured (erect) from its intersection with the dorsal groove to its tip. This character is a good quantitative indicator of the ontogenetic changes in height undergone by the first dorsal fin.

41.—*Anterior height of second dorsal.*—Measured from the origin of the second dorsal fin (See second predorsal length) to the tip of its anterior lobe.

42.—*Height of first anal.*—Measured according to the same procedure described above for the anterior height of first dorsal.

43.—*Anterior height of second anal.*—Measured according to the same procedure described above for the anterior height of second dorsal.

44.—*Length of pectoral.*—Measured from the origin of the pectoral fin (See prepectoral length) to its tip, with the anterior basal margin of the fin perpendicular to the body.

45.—*Length of pelvic.*—Measured according to the same procedure described above for the length of the pectoral. The fin should be held straight and stretched to its full length.

46.—*Length of second dorsal.*—Measured from the origin of the second dorsal fin (See second predorsal length) to the tip of the last (suctorial) ray held straight and against the middorsal line of the back.

47.—*Length of second anal.*—Measured according to the same procedure described above for the length of second dorsal.

48.—*Length of upper caudal lobe.*—Measured from the posterior end of the upper caudal keel to the tip of the upper caudal fin lobe.

49.—*Length of lower caudal lobe.*—Measured according to the same procedure described above for the length of upper caudal lobe, but using the end of the lower keel as point of reference.

50.—*Caudal spread.*—Measured between the tips of the caudal fin lobes.

51.—*Caudal angle.*—Measured by joining three points of reference represented by the tips of the caudal fin lobes and the middle point on the posterior margin of the middle caudal ray. This character is a good

quantitative indicator of the change of angulation and concavity of the caudal fin among species and ontogenetically within a species.

Counts

1.—*Dorsal spines.*—The number of dorsal spines has not been widely used as a taxonomic character in billfishes and there is reason to believe that most of the few counts reported in the literature are not accurate.

Careful inspection of the anterior part of the dorsal fin will show that the first two or three spines are very close together, and therefore difficult or impossible to count without dissection. Very often the first and even the second spine is extremely short. They are easily missed if the skin covering is not peeled off to the base of the fin and the spines separated with the point of the knife. Posteriorly, and especially in adult marlins, the dorsal spines gradually decrease in length and become very short or obsolete as the second dorsal fin is approached. This condition appears to be correlated with growth, since in the postlarval and juvenile stages of billfishes (Beebe, 1941; Arata, 1954) the first dorsal fin is continuous with the second, but in the young adult stages, a gap appears externally between these two fins. This gap becomes progressively longer as the fish becomes older and is quite extensive in very large specimens.

Dorsal spine counts in billfishes without consideration of the above facts, would be inaccurate and lead to false taxonomic interpretations, when samples of widely differing age groups are compared. Dissection of the anterior part of the fin obviously should always be made, and posteriorly, attention should be paid to the magnitude of the gap and the resulting degree of external discontinuity between the first and second dorsal fins. If the distance between the last dorsal spine and the origin of the second dorsal fin is about equal to or somewhat greater than the distance between the last dorsal spine and the preceding one, no obsolete spines are then present. It is recommended that if the gap is of a magnitude indicating the existence of one or more obsolete spines the dorsal spine count be followed by the sign plus (+).

2.—*Dorsal rays.*—All rays are counted. In this fin the rays are easily made out without dissection.

3.—*Anal spines.*—Counted according to the same procedure described above for the dorsal spines. The discussion given above in connection with the dorsal spines also applies to the anal spines.

4.—*Anal rays.*—Same procedure as described above for the dorsal rays.

5.—*Pectoral rays.*—All rays are counted. Although all rays are made out in this fin without dissection, care must be taken that the posterior part of the fin is well spread out so that the very small posterior rays are not missed.

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MONOGENETIC TREMATODES OF GULF OF MEXICO FISHES. PART XII. THE FAMILY GASTROCOTYLIDAE PRICE, 1943[1]

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ABSTRACT

This paper is the twelfth installment of the present series presenting the data concerning monogenetic trematodes collected during the years 1951-1954 at the Alligator Harbor Marine Laboratory of Florida State University. It comprises an emendation of the family Gastrocotylidae Price, 1943 and the subfamily Gastrocotylinae Sproston, 1946 and descriptions and/or discussions of several species.

The new genera *Scomberocotyle* and *Neothoracocotyle* have been diagnosed with *Scomberocotyle scomberomori* (Koratha, 1955) n. comb. and *Neothoracocotyle coryphenae* (Yamaguti, 1938) n. comb., respectively as their type species. Emendations have been made in *Gotocotyla* Ishii, 1933, *Thoracocotyle* MacCallum, 1913, and *Lithidocotyle* Sproston, 1946. *Pseudaxine mexicana* Meserve, 1938, *Lithidocotyle acanthophallus* (MacCallum and MacCallum, 1913) Sproston 1946, *Gotocotyla elegatis* Meserve, 1938, *Neothoracocotyle acanthocybii* (Meserve, 1938) n. comb., and *Thoracocotyle crocea* MacCallum, 1913 have been treated. *T. paradoxica* has been reduced to synonymy with *T. crocea.*

In addition several notes concerning host-specificity, zoogeography, speciation and other biological facets have been presented.

INTRODUCTION

This paper continues presentation of the data concerning members of the suborder Polyopisthocotylea Odhner, 1912 obtained during a recent study of these ectoparasites of fishes. This study was conducted at the Alligator Harbor Marine Laboratory of Florida State University. Specifically treated are several members of the subfamily Gastrocotylinae Sproston, 1946. Some of these species are refigured and described. Of greater importance are the many taxonomic changes which were necessitated by the new data from this collection. These changes include the revival of Price's (1943) family Gastrocotylidae and emendations in the subfamily Gastrocotylinae and several of its genera.

All measurements were made using the ocular micrometer and are cited in millimeters. In the cases of curved structures, measure-

[1]Contribution from the Virginia Fisheries Laboratory and the Zoology Department of Florida State University.

This series is dedicated to Mrs. Dolores M. Hargis and Dr. Perry C. Holt. Thanks for aid and/or advice are due to Dr. E. W. Price of the U. S. Dept. of Agriculture, Dr. Harold J. Humm of Duke University and Dr. Robert B. Short of Florida State University.

ments are of the lines subtending the greatest arcs of those structures. In the descriptions the mean is given first, followed by the minima and maxima in parenthesis. The number of measurements used to derive the mean is usually the same as the number of individuals measured; otherwise, the actual number employed appears in parentheses before the measurements. All drawings were made with the aid of the camera lucida. Types of several species have been deposited in the USNM Helminthological Collection at Beltsville, Md.

Results

Suborder *POLYOPISTHOCOTYLEA* Odhner, 1912

Superfamily DICLIDOPHOROIDEA Price, 1936

Family Gastrocotylidae Price, 1943, *diag. emend.*

Diagnosis: Diclidophoridae. Body variable in shape, often asymmetrical and bearing from seven to numerous clamps which are usually arranged in two lateral rows. Clamp skeletons possess extra sclerites and may or may not be asymmetrical or fully open and sessile. Ventral loop incomplete medially, center piece present and either plain or loop incomplete medially, center piece present and either plain or highly modified in shape, accessory middle loop sclerites in the shape of elongate, slightly curved pieces present terminally in the middle loop wall, and accessory wall sclerites often present. One to three pairs of anchors usually present at the end of the haptor. Testes usually numerous, follicular, postovarial (Gastrocotylinae) or preovarial (Vallisiinae). Cirrus usually armed. Genital pore midventral, may be armed. Vaginal pore lateral or middorsal, may be armed.

Type genus: *Gastrocotyle* van Beneden and Hesse, 1863.

Discussion: Gastrocotylidae Price, 1943 is brought back from the synonymy to which Sproston (1946) reduced it in order to accommodate the subfamilies Gastrocotylinae Sproston, 1946 and Vallisiinae Price, 1943 and others which may later be adjudged similar. Price (1943) named this family and described it by reference to a diagram of the clamp type alone, and no further discussion or description was given. Because the family is recognizable, even with so few details, Price's name is employed herein and *Gastrocotyle* is designated the type genus. Dawes (1947) recognized and diagnosed the family Gastrocotylidae but his diagnosis did not include the vallisiinids and contained only the type genus, *Gastrocotyle*. (Although the paper by Chauhan (1953) was not received in time to be considered herein, it is evident that he, too, considers this family

valid and useful. He includes another subfamily, Priceinae Chauhan, 1953, therein. The details of this inclusion will be considered in a later installment.)

Gastrocotylinae is removed from Microcotylidae, where Sproston (1946) and others have placed it, on the basis of the gastrocotylid nature of its clamps. It is reoriented with the subfamily Vallisiinae in the family grouping Gastrocotylidae. Although Vallisiinae is more clearly delineated morphologically from Microcotylidae than Gastrocotylinae, the name Gastrocotylidae is employed for this family because Price (1943) and Dawes (1947) have used it previously.

Vallisiinae is removed from the family Discocotylidae, in which Sproston (1946) and others have placed it, on the basis of recent studies by Yamaguti (1953) and the present writer which indicate that the type genus *Vallisia* Perugia and Parona, 1890 possesses the necessary accessory middle loop sclerites, similar anchors and other features in common with Gastrocotylinae.

Palombi (1949) did not recognize Price's (1943) subfamily Vallisiinae or Sproston's (1946) subfamily Gastrocotylinae but placed the former in the subfamily Discocotylinae Price, 1936 and the latter in the subfamily Microcotylinae Monticelli, 1892. He then placed both of these subfamilies in his own family Arreptocotylidae, an arrangement which is not adopted herein because it is at variance with the present evidence.

Subfamily Gastrocotylinae Sproston, 1946, *diag. emend.*

Diagnosis: Gastrocotylidae. Body elongate, flattened dorso-ventrally, often laterally or ventrally asymmetrical. Opisthaptor a cotylophore which is often asymmetrical, bearing many clamps ventrolaterally and armed by two or three pairs of gastrocotylid anchors. Clamps typically gastrocotylid in nature, with accessory middle loop sclerites and, often, short accessory wall sclerites. Clamps asymmetrical in some genera. Testes numerous, in posterior region of body. Cirrus may be armed, if armed it usually has multiple spines. Genital atrium armed or not, armature simple. usually consisting of a ring-like corona. Ovary regularly pretesticular. Vagina middorsal, armed or merely muscular.

Type genus: *Gastrocotyle* van Beneden and Hesse, 1863.

Discussion: The above emendation is made because of the transfer of this subfamily from Microcotylidae to Gastrocotylidae which is necessitated by its gastrocotylid characteristics. Gastrocotylinae differs from Vallisiinae, the other subfamily, in the following features: (1)

cotylophore not grooved between clamps on one side, (2) cotylophore bearing numerous clamps and not eight or less, (3) ovary pretesticular, (4) clamps of some genera asymmetrical, (5) none of its known genera retain the entire larval opisthaptor.

As presently conceived the subfamily Gastrocotylinae contains the following genera: *Scomberocotyle* n. gen., *Pseudaxine* Parona and Perugia, 1890, *Gotocotyla* Ishii, 1933, *diag. emend., Thoracocotyle* MacCallum, 1913, *diag. emend., Neothoracocotyle* n. gen., and *Lithidocotyle* Sproston, 1946, *diag. emend.* An additional gastrocotylinid genus will be described in the next installment.

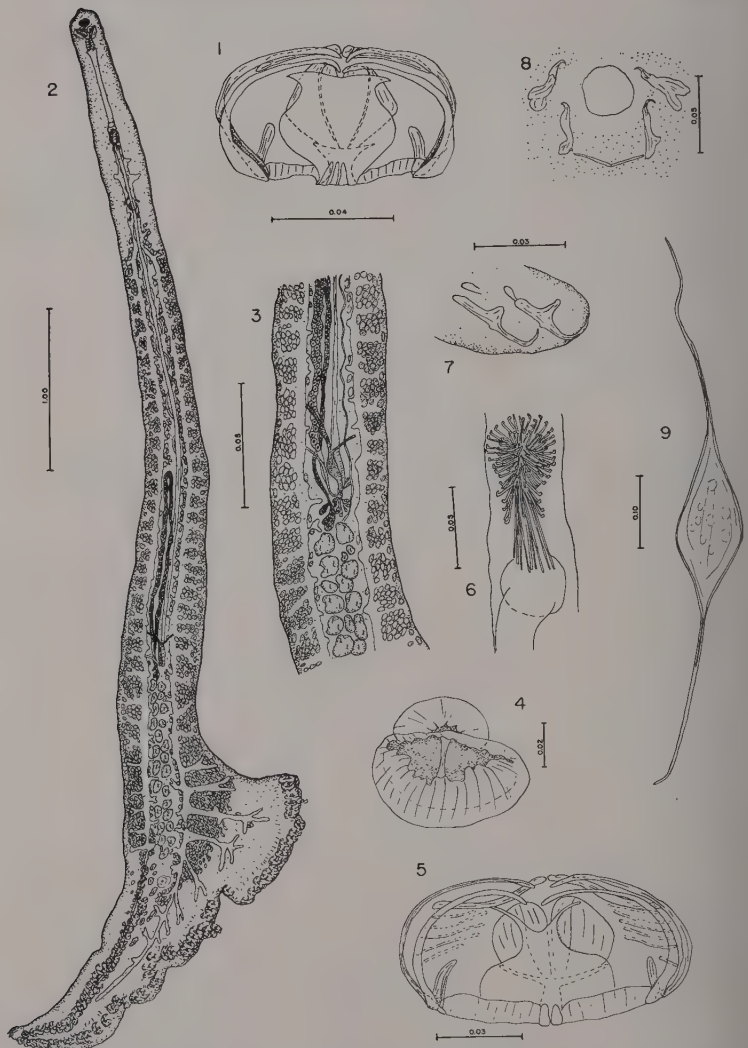
The subfamily Gastrocotylinae is apparently more closely related to Microcotylidae than Vallisiinae is. This possible relationship is arrested by its multiple clamps and middorsal vagina.

Genus *Scomberocotyle* n. gen.

Diagnosis: Gastrocotylinae. Body elongate, flattened dorso - ventrally, widened posteriorly. Opisthaptor an asymmetrical cotylophore with the larval posterior end lateral. Clamps gastrocotylid in nature. symmetrical, with the center piece widened and much modified, in two rows with a short row of fewer clamps, on the antero-laterally oblique edge and the long row on the posterolaterally oblique edge. Embryonically posterior end armed with one pair of anchors. Testes numerous, in posterior part of body. Cirrus armed with many spines. Vaginal atrium middorsal, armed with several spines. Ovary pretesticular. Large nucleus may be present on haptor between posterior end of the intestinal crura.

Type species: *Scomberocotyle scomberomori* (Koratha, 1955) n. comb.

Discussion: This genus is erected to accommodate the type species *S. scomberomori* (Koratha, 1955) n. comb. which is considered sufficiently different in several taxonomically important structures to require such action. *Scomberocotyle* n. gen. appears to be most closely related to the genus *Pseudaxine* Parona and Perugia, 1890, from which it differs in the following characters: (1) opisthaptor more angular, (2) clamps arranged in two unequal, lateral rows, (3) details of clamp center piece, (4) cirrus armed with numerous long spines, (5) genital atrium not armed with genital corona. It is not considered similar to the microcotylinid genus *Heteraxine* into which the type species was originally placed.



Pseudaxine mexicana. FIGURE 1, Clamp, ventral view.

Scomberocotyle scomberomori (Koratha, 1955) n. comb. FIGURE 2, Whole mount, ventral view; FIGURE 3, Enlargement showing female internal genitalia; FIGURE 4, Enlargement of buccal sucker; FIGURE 5, Clamp, ventral view; FIGURE 6, Cirrus; FIGURE 7, Anchors; FIGURE 8, Vaginal pore, showing armature; FIGURE 9, Egg, *in utero*.

Scomberocotyle scomberomori (Koratha, 1955) n. comb.
(Figures 2 to 9)

Hosts: *Scomberomorus maculatus* (Mitchill), Spanish Mackerel and *S. cavalla* Cuvier and Valenciennes, King Mackerel, neritopelagic marine scombrids.

Location: Gills.

Localities: Alligator Harbor, Franklin Co., Florida, Tampa Bay, Pinellas Co., Florida, and "Off Port Aransas, Texas" (Koratha, 1955).

Number studied: 5.

Number measured: 3.

Homotype in USNM Helm. Coll., No. 37494.

Description: Body elongate, flattened dorso-ventrally, 6.1 (5.5—6.5) long by 0.6 (0.5—0.7) wide, widened posteriorly to haptor. Cuticle thick, with delicate transverse striae. Prohaptor a pair of biloculate buccal suckers, about 0.074 (0.073—0.076) long by 0.051 (0.047—0.058) wide, with a small, hollow anterior protrusion. Opisthaptor an asymmetrical cotylophore, 2.3 (2.2—2.4) long, embryonically posterior end lateral, bearing 134 clamps in two converging lateral rows, a short row of 50 clamps, on the oblique right edge and a long row of 84 clamps, opposite; larval end on right tip armed with a pair of anchors and a pair of flask-shaped cuticular pieces. Clamps dissimilar in size, middle clamps, 0.090 (0.088—0.095) long by 0.055 (0.043—0.068) wide, posterior clamps, (2) 0.050 (0.047—0.053) long by (2) 0.032 (0.031—0.032) wide; similar in shape with delicate sclerites, ventral loop incomplete medially, dorsal loop elements stout, middle loop incomplete medially, center piece bizarrely sculptured, accessory middle loop sclerites, other short accessory sclerites present. Anchors with stout shafts and hooks, (2) 0.030 long, flask-shaped structures near anchor shaft. Mouth subterminal. Pharynx ovoid, 0.061 (0.055—0.067) long by 0.041 (0.040—0.042) wide; esophagus very long, laterally ramified. Gut bifurcated near anterior one-fourth body level, crura ramified, rami branched, crura not confluent posteriorly, extending into haptor. Curious, very large, nucleus-like structure situated between crura on haptor. Testes follicular, 27-38 in number, between intestinal crura in posterior one-fourth of body, few follicles in haptor; vas deferens, narrow, sinuous, coursing anteriorly to cirrus. Cirrus muscular, 0.117 (0.110—0.140) long by 0.045 (0.042—0.047) wide, armed with numerous spines of two types, short spike-like spines, 0.014 (0.012—0.016) long, long

straight spines, 0.075 (0.061—0.085) long. Genital pore midventral, about halfway along the esophagus, opening into genital atrium. Ovary pretesticular, very long, tubular, folded; oviduct running medially from right ovarian lobe. Ootype dorsal to vitelline-reservoir; uterus long and narrow. Genito-intestinal canal running from right crus medially to fuse with oviduct. Vaginal pore middorsal at anterior one-fourth level, vaginal atrium armed with 2 pairs of dorso-laterally placed curved spines. Mehlis' gland present. Vitellaria follicular, near intestinal crura, extending from level shortly posterior to vaginal atrium to middle of haptor; transverse vitelloducts fusing medially to form Y-shaped vitelline reservoir. Egg *in utero* fusiform, (2) 0.138 (0.094—0.182) long by (2) 0.048 (0.041—0.055) wide, with a filament at each end. Brain and excretory vesicles not observed.

Discussion: Although Koratha (1955) apparently did not realize it this species is sufficiently different from other members of the subfamily to be considered the type species of a new genus.

The large nucleus in the haptor may be of some interest to cytologists.

Pseudaxine mexicana Meserve, 1938
(Figure 1)

Hosts: *Scomberomorus maculatus* (Mitchill), Spanish Mackerel and *S. cavalla* Cuvier and Valenciennes, King Mackerel, nerito-pelagic marine scombrids.

Location: Gills.

Locality: Alligator Harbor, Florida and Grand Isle, Louisiana.

Previously reported host and locality: *Scomberomorus maculatus* Tangola-Tangola, Mexico (Pacific).

Number studied: 4.

Discussion: This species is in need of complete redescription.

A comparison of Meserve's (1938) specimens on USNM Helm. Coll. slide No. 9167 with the present specimens yields the following morphological information. In this species, as well as in many other monogenetic trematodes which feature asymmetrical development of the opisthaptor, the direction of asymmetry may be either left or right but the relative positions of the internal organs appear to remain constant. The clamp sclerites differ markedly from Meserve's representation. The genito-intestinal canal, originally figured but not described, is somewhat longer than Meserve drew it and meets the right crus immediately posterior to the crossing of the right transverse vitelloduct.

P. mexicana parasitixes both *Scomberomorus maculatus* and *S. cavalla*. This habit of parasitism is properly a reflection of the relationship of hosts.

The occurrence of the present species on both sides of the Isthmus of Panama may be an indication of the length of time required for noticeable speciation to occur in this fluke group (provided the host is not continuous around South America). Even though the Isthmus of Panama has separated the Gulf from the Pacific since upper Pliocene times the flukes from both localities are still so similar morphologically as to be considered conspecific. In speculations regarding problems of this nature it must be remembered that probably the parasites would have evolved more slowly than the hosts due to the less pronounced changes in their immediate environment requiring such evolution.

It is probable that *Pseudaxine texana* Koratha, 1955 is synonymous with the present species; however, the type specimen has not been received by the USNM Helm. Coll. at this writing, and it is not possible to ascertain this until it is available.

Genus *Lithidocotyle* Sproston, 1946, *diag. emend.*

Diagnosis: Gastrocotylinae. Diagnosis the same as that of Sproston (1946) except as follows: Clamps asymmetrical, with the medial elements of the ventral and dorsal loops smaller than the lateral elements so that the medial side of the clamp is smaller than the lateral. Center piece shifted medially and much modified. Anchors retained by the adult. Testes numerous, follicular, situated in the posterior field between the intestinal crura. Vaginal pore middorsal, surrounded by a wide band of circular muscles.

Type species: *Lithidocotyle acanthophallus* (MacCallum and MacCallum, 1913), Sproston, 1946.

Discussion: This emendation has been made in order to separate *Lithidocotyle* from its close relative *Gotocotyla*.

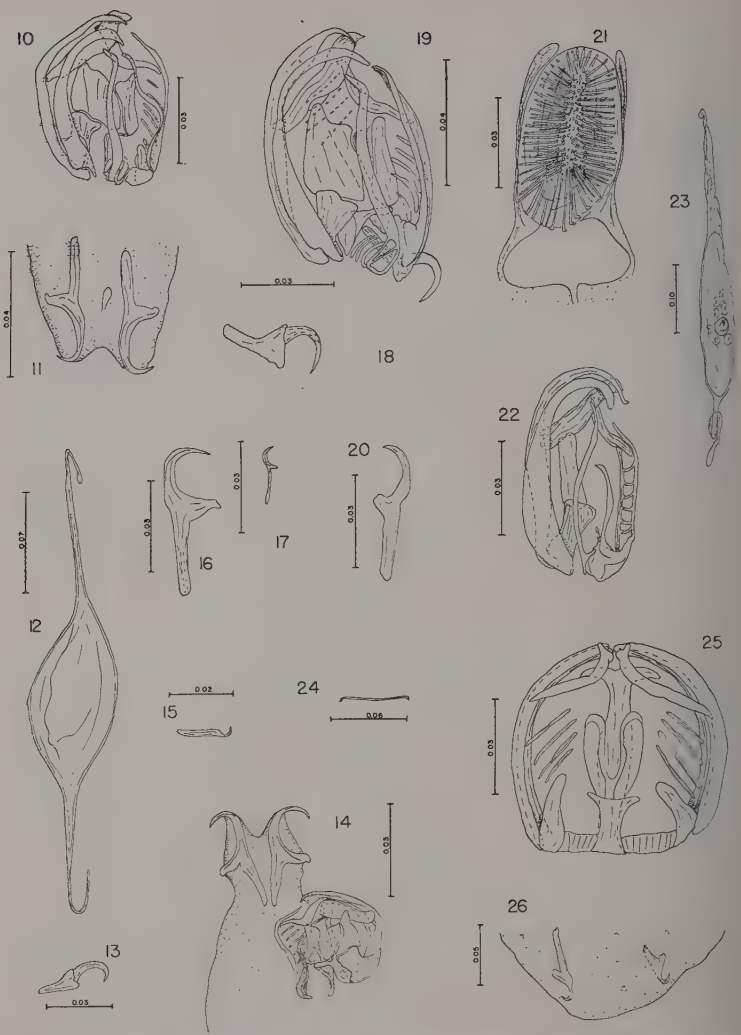
Lithidocotyle acanthophallus (MacCallum and MacCallum, 1913), Sproston, 1946

(Figures 10 to 19)

Hosts: *Scomberomorus cavalla* Cuvier and Valenciennes, King Mackerel and *S. maculatus* (Mitchell), Spanish Mackerel, nerito-pelagic marine scombrids.

Location: Gills.

Localities: Alligator Harbor, Florida, Tampa Bay, Florida and Grand Isle, Louisiana.



Lithidocotyle acanthophallus from *Scomberomorus cavalla*. FIGURE 10, Clamp, ventral view; FIGURE 11, Anchors.

Lithidocotyle acanthophallus from *Scomberomorus maculatus*. FIGURE 12, Egg, *in utero;* FIGURE 13, Embryonic anchor; FIGURE 14, Clamp and anchors, dorsal view; FIGURE 15, Cirrus spine; FIGURE 16, Anchor; FIGURE 17, Larval anchor.

Lithidocotyle acanthophallus from *Roccus saxatilis*. FIGURE 18, Larval anchor; FIGURE 19, Clamp, ventral view.

Gotocotyla elagatis. FIGURE 20, Anchor; FIGURE 21, Cirrus; FIGURE 22, Clamp, ventral view; FIGURE 23, Egg, *in utero*.

Neothoracocotyle acanthocybii. FIGURE 24, Cirrus spine; FIGURE 25, Clamp, dorsal view; FIGURE 26, Anchors.

Previously reported host and locality: *Roccus saxatilis* (Walbaum) [*R. lineatus*], from N. Y. fish market (MacCallum and MacCallum, 1913), probably collected in the Atlantic Ocean (see below).

Number studied: 86.

Discussion: A study of the USNM Helm. Coll. slide No. 36358, containing the type and only known specimen of this species until the present time, resulted in the determination of the forms in this collection as *Lithidocotyle acanthophallus*. The clamp sclerites are asymmetrically developed as noted above under the generic diagnosis. Terminal anchors persist in the adult. In addition, some larval anchors may also persist anteriorly on the opisthaptor between and dorsal to the clamp rows. The "uterine opening" of the original authors is really a middorsal vaginal pore.

Although Sproston (1946) placed the original locality of the host as the N. Y. Aquarium, a study of several of MacCallum's type slide labels of various species indicates that the host may have come from the fish market instead. The slide actually was labelled N. Y., and it apparently was the habit of the elder MacCallum to put "N.Y." for the fish market, "Aq." for the N.Y. Aquarium and "H" or the full name for Woods Hole on his labels. Of course, the locality could have been the aquarium. Whether the host came from the fish market or the aquarium the present writer strongly suspects that *Roccus saxatilis* is not a natural host for this parasite and that *Scomberomorus cavalla* and *S. maculatus* are. The reasons supporting this suspicion are: (1) neither of the possible collecting sites used by the MacCallums can be depended upon to yield accurate host data, (2) though only one specimen was taken from *Roccus* and none has been reported since 1913, 86 were taken from the two *Scomberomorus* spp. —most came from three individuals, (3) *Roccus* and *Scomberomorus* are in two different host families and it is unusual for a single monogenetic species to parasitize members of different families in nature.

In the early part of the study it was suspected by the writer that several species of *Lithidocotyle* were represented in the collection because those from *S. maculatus* were much smaller than those from *S. cavalla*. However, later study revealed overlaps in many of the countable and measurable characters and such a similarity of organs that it is impossible to consider either of the populations from these two host species as new. Because later study with more worms from the hosts involved, provided *Roccus saxatilis* is a natural host, may reveal differences of taxonomic value, possibly subspecific in nature, the

clamps and anchors of the worms from all three host species are figured separately herein.

The occurrence of *L. acanthophallus* in such numbers on both *S. cavalla* and *S. maculatus* may reflect the close relationship of the hosts. *S. cavalla* is probably the more favorable host because it harbored many more and much larger worms per host than *S. maculatus*. It is very probable that *Microcotyle scomberomori* Koratha, 1955 is synonymous with the present species but the original descriptions and figures are inadequate and the holotype has not been received by the USNM Helm. Coll. at this writing. A decision cannot, therefore, now be reached.

Genus *Gotocotyla* Ishii, 1936 *diag. emend.*

Diagnosis: Gastrocotylinae. Body proper not noticeably set off from opisthaptor, *i.e.* no noticeably constricted peduncle. Opisthaptor usually V-shaped, bearing numerous clamps in two more or less equal rows, one row may be augmented by an additional, shorter, medial row of clamps, *e.g. Gotocotyla elegatis* Meserve, 1938. Clamp sclerites typically gastrocotylinid with accessory middle loop sclerites and accessory wall sclerites, but markedly asymmetrical in development with the medial elements of both the ventral and middle loops reduced, center piece profoundly altered in shape and broad sclerites present in the middle loop walls. Testes numerous, extending lateral to intestinal crura to body margin. Cirrus armed with many spines. Genital atrium usually unarmed. Anchors of the gastrocotylinid type retained in the adult. Middorsal vagina apparently present or absent.

Type species: *Gotocotyla sawara* Ishii, 1936.

Discussion: The above emendation is made in order to include and emphasize the gastrocotylinid characters of this genus. Sproston (1946) and others have placed *Gotocotyla* in the subfamily Microcotylinae Monticelli, 1892 to which it obviously does not belong by virtue of its extra clamp sclerites and asymmetrical clamp development.

The genus *Gotocotyla* includes the following species: *G. sawara* Ishii, 1936, *G. elegatis* Meserve, 1938 and *G. meservei* Yamaguti, 1953. *G. acanthura* (Parona and Perugia, 1896) Meserve, 1938 has been figured and described with such lack of detail that its precise affinities are uncertain; therefore, it is retained in the genus only provisionally, pending further study.

Gotocotyla is very similar to the genus *Lithidocotyle* from which

it differs in the following characters: (1) testes located laterally as well as medially to intestinal crura, (2) cotylophore not clearly set off from the rest of body by a peduncle. Later work may show that these genera, which are so similar in the asymmetrical modification of their clamps are only of subgeneric stature. It is also possible that they will be found to constitute a supergenus.

Gotocotyla elegatis Meserve, 1938.
(Figures 20 to 23)

Host and locality: *Elegatis bipinnulatus* (Quoy and Gaimard) from Bahia Honda, Panama.

Discussion: This species was not taken in the present collection but it is included here for taxonomic purposes. A study of USNM Helm. Coll. type slide No. 9173 indicates that the species needs redescription. Though this redescription is not presently possible some additional data have been obtained. As mentioned above in the generic diagnosis the clamps are much modified. Apparently there are two left rows of clamps, one long and lateral and the other short. medial and situated near the anterior end of the long clamp row. The testes are both between and lateral to the intestinal crura posteriorly. The structure which Meserve (1938) termed a genital atrium is really the armed cirrus. The genito-intestinal canal proceeds anteriorly from the middle of the body to join the right crus near the right transverse vitelloduct. The egg, figured herein, is fusiform with filaments at both ends.

Genus *Neothoracocotyle* n. gen.

Diagnosis: Gastrocotylinae. Body elongate, flattened and symmetrical dorso-ventrally. Opisthaptor a cotylophore in the form of two lateral, clamp bearing flanges which extend anteriorly to a nearly equatorial level. Clamps typically gastrocotylinid with the clamp valves opposable end not open as in *Thoracocotyle* MacCallum, 1913; ventral loop incomplete medially and curved toward the dorsal loop elements, middle loop incomplete medially and acting in opposition to the ventral loop, center piece with expanded ends, accessory middle loop sclerites and accessory wall sclerites not heavily cuticularized. Most of the internal genitalia situated in the posterior region of the body between the clamp rows. Testes postovarial. Genital atrium armed. Vagina middorsal.

Type species: *Neothoracocotyle coryphenae* (Yamaguti, 1938) n. comb.

Discussion: *Neothoracocotyle* n. gen. is erected to accommodate *N. coryphenae* (Yamaguti, 1938) n. comb. [*Thoracocotyle coryphenae* Yamaguti, 1938] and *N. acanthocybii* (Meserve, 1938) n. comb. [*Gotocotyla acanthocybii* Meserve, 1938]. *N. coryphenae* was chosen as the type species because it is better known.

This genus differs strikingly from *Thoracocotyle* MacCallum, 1913 in the following characters: (1) cotylophore not asymmetrically set-off from the rest of the body, (2) clamps act as clamps and are not modified into sucker-like, open structures, (3) accessory sclerites not heavily cuticularized, (4) genital atrium armed.

Neothoracocotyle acanthocybii (Meserve, 1938) n. comb.
(Figures 24 to 26)

Synonym: *Gotocotyla acanthocybii* Meserve, 1938.

Host and locality: *Acanthocybium solandri* from the Galapagos Island.

Discussion: The present species was not taken in this collection but is included for taxonomic reasons. An examination of USNM Helm. Coll. type slide No. 9174 indicates that this species is in need of redescription. This study established the fact that the clamps are distinctly gastrocotylinid in structure like those on *N. coryphenae* (Yamaguti, 1938) n. comb. and not asymmetrical like those of various *Gotocotyla* spp. In addition, the general body shape and arrangement of internal organs are similar to those of the type species of *Neothoracocotyle* n. gen. For these reasons this recombination is made.

The clamps of the species of *Neothoracocotyle* are very similar to those of members of the subfamily Vallisiinae Price, 1936 and may indicate some close phylogenetic relationship between the two groups.

Genus *Thoracocotyle* MacCallum, 1913, *diag. emend.*

Diagnosis: Gastrocotylinae. Body elongate, anterior end somewhat flattened dorso-ventrally, posterior end asymmetrical dorso-ventrally so that there are two distinct body areas, a broad, ventrally expanded foot-like posterior part and a slender, neck-like anterior part, somewhat similar to the shape of certain aspidogastreds. Opisthaptor a cotylophore with two rows of more-or-less sessile clamps placed ventro-laterally on the broad foot. Clamp structure clearly related to that of other gastrocotylinids, with the necessary extra sclerites, but much modified so that they are apparently permanently open and function like suckers rather than clamps. Testes and ovaries and most of other

genitalia situated in the "foot" medio-dorsal to the clamp rows. Genital atrium armed or unarmed.

Type species: *Thoracocotyle crocea* MacCallum, 1913.

Discussion: The above emendation is made in order to more clearly separate this genus from others in the subfamily Gastrocotylinae, particularly *Neothoracocotyle*.

Thoracocotyle crocea MacCallum, 1913

Synonyms: *Thoracocotyle croceus* MacCallum, 1913, another spelling synonym of Sproston (1946), *T. paradoxica* Meserve, 1938, of Hargis (1954), and, probably, *T. paradoxica* of Pearse (1949).
Host: *Scomberomorus maculatus* (Mitchill) Spanish Mackerel, a nerito-pelagic marine scombrid.
Location: Gills.
Locality: Alligator Harbor, Florida.
Previously reported hosts and localities: *Scomberomorus maculatus* from Tangola-Tangola, Mexico (Meserve, 1938) and the N. Y. Aquarium, (MacCallum, 1913) and (probably) *S. cavalla* from Beaufort, N. C. (Pearse, 1949).
Number studied: 15.

Discussion: A study of MacCallum's (1913) specimens on USNM Helm. Coll. slide No. 35588, the specimens in the present collection and the literature involved, indicates the conspecificity of the present specimens and MacCallum's. In addition, there is very strong evidence that Meserve's (1938) suspicion that his species, *T. paradoxica*, was conspecific with *T. crocea* is verified. Because of the overlap of the countable and measurable characteristics and the close similarity in internal structure and the host, Hargis' (1954) synonymization is hereby supported.

Pearse (1949) reported *T. paradoxica* from *Scomberomorus cavalla* at Beaufort, N. C. stating that it could not be described as new because no whole worms were taken and, "It occurred in the same host as Meserve's species". This last observation is incorrect since Meserve's (1938) worm came from *S. maculatus*. Pearse's monogeneid is probably synonymous with the present species, but it must be left for later study to verify this possibility definitely.

Summary

The family Gastrocotylidae Price, 1943 *diag. emend.* has been revived and discussed. The subfamily Gastrocotylinae Sproston, 1946

and its genera *Gotocotyla* Ishii, 1933, *Thoracocotyle* MacCallum, 1913 and *Lithidocotyle* Sproston, 1946 have also been emended and discussed. In addition the new genera *Scombercocotyle* and *Neothoracocotyle* have been described.

The species which have been described and/or discussed are: *Scombercotyle scomberomori* (Koratha, 1955) n. comb., *Pseudaxine mexicana* Meserve, 1938, *Lithidocotyle acanthophallus* (MacCallum, and MacCallum, 1913) Sproston, 1946, *Gotocotyla elegatus* Meserve, 1938, *Neothoracocotyle acanthocybii* (Meserve, 1938) n. comb. [*-Gotocotyla acanthrocybii* Meserve, 1938] and *Thoracocotyle crocea* MacCallum, 1913. This is a new locality report for all and new host records for some of the previously described species. New combinations are also made for *Neothoracoctyle coryphenae* (Yamaguti, 1938) n. comb. [*Thoracocotyle coryphenae* Yamaguti, 1938]. It is herein affirmed that *Thoracocotyle paradoxica* Meserve, 1938 is synonymous with *T. crocea* MacCallum, 1913.*

Several notes concerning host-specificity, zoogeography, speciation and other items of general biological interest have also been presented herein.

The next installment will complete treatment of the data on the family Gastrocotylidae.

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NOTES ON THE BORING SPONGES IN GULF COAST ESTUARIES AND THEIR RELATION TO SALINITY

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ABSTRACT

Four species of *Cliona* have been identified in Louisiana oyster shells: *C. celata* Grant, *C. lobata* Hancock, *C. vastifica* Hancock, and *C. truitti* Old. These differ in tolerance to low salinity and may be used as salinity indicators. A tentative division of Louisiana estuarine waters into 6 zones is made on the basis of presence or absence and relative abundance of *C. truitti* (low salinity species) and *C. celata* (high salinity). The zones correspond to differences in frequence of low salinities, as shown by daily or continuous salinity records over periods of one year or more.

INTRODUCTION

The Gulf of Mexico has a rich sponge fauna. However, very few sponges live in the bays or estuaries, in contrast to the situation on the Atlantic coast. The shallow inshore waters of Louisiana and Texas are especially poor in sponges; the bays of these states usually have only encrusting forms of *Haliclona* and *Microciona,* and boring sponges of the genus *Cliona*. *Microciona* extends well up into Texas bays in years of low rainfall; it was seen in Copano Bay in 1949 when the salinity was between 18 and 23 parts per thousand. *Haliclona* is abundant in both Texas and Louisiana bays at salinities as low as 20 or even 15 parts per thousand, but is easily overlooked because of its encrusting form and its lack of conspicuous color.

Cliona celata is the most conspicuous of the boring sponges, and is the only one noticed by most collectors. The large dome-shaped or vase-like forms which occur in the open Gulf and in the larger bays of the Atlantic states are not found in Gulf coast bays, but encrusting forms of *C. celata* are fairly common and boring forms, in old oysters and in dead shells, are very common. However, other species of *Cliona* are much more abundant than *C. celata* on the oyster beds. There is not much excuse for calling all boring sponges *Cliona celata* as most naturalists still do; with the excellent publication of Old (1941) as a guide, even a beginner can easily identify the other species of *Cliona*. The writer, beginning in 1948, has positively identified

four species from Louisiana bays: *C. celata* Grant, *C. lobata* Hancock, *C. vastifica* Hancock, and *C. truitti* Old. It seems probable that additional species will be found on the Gulf coast if more biologists will search for them.

The identification of the species of *Cliona* is important because they differ in their salinity tolerances. *Cliona celata* and *C. truitti,* especially, are excellent indicators of the salinity regime. Such indicators are particularly important in the Gulf coast estuaries where the salinity changes so much from day to day, or even from hour to hour, that a study based on spot samples is not reliable. Fortunately, the author has been able to compare the distribution of the boring sponges in Louisiana bays with several series of continuous salinity records, obtained by conductivity measurements and checked by titration. These salinity records were assembled, tabulated, and graphed for the Texas A. and M. Research Foundation by Dr. Willis G. Hewatt of Texas Christian University. In nearly all cases, the salinity was measured one foot above the bottom.

All laboratory work described herein was done by the author in the Grand Isle laboratories of Louisiana State University and the Texas A. and M. Research Foundation. Thanks are due to Dr. J. G. Mackin and Mr. D. A. Wray for some of the field data.

Methods

Permanent slides of the four species of *Cliona* were prepared by Old's method. Pieces of sponge or of sponge-riddled shell were placed in a beaker with concentrated nitric acid and heated until the calcium carbonate was completely dissolved. After cooling, the beaker was filled with water. When the spicules had settled to the bottom, most of the fluid was siphoned off or decanted and the beaker was refilled with water. This washing process was usually repeated several times. The water was then replaced by 95% ethyl alcohol. A portion of the alcoholic suspension of spicules was drawn off with a medicine dropper and placed on a slide. The alcohol was then ignited and allowed to burn off. At this point a modification of Old's method was made: instead of placing balsam directly on the film of spicules after the alcohol was burned off, a drop of carbol-xylol was placed on the slide before balsam was added. A cover slip was then placed on the slide. The modification was suggested by Dr. J. G. Mackin. Carbol-xylol, a half-and-half mixture of phenol and xylol, removes the film of water clinging to the spicules.

For routine identification of large numbers of specimens, small pieces of sponge or of sponge-riddled shell may be placed on slides lined up on a plate of glass. Large drops of concentrated nitric acid are then placed on the slides and allowed to stand until bubbling stops. The specimen slides are then covered with large cover slips and examined under a microscope. Care must be used to avoid corrosion of the stage and other parts of the microscope. It is important to avoid contamination of the specimen with *Haliclona,* for this genus has spicules very similar to the oxeae of some species of *Cliona.*

Cliona vastifica, C. truitti, and *C. lobata* can not be distinguished from each other without microscopic examination, but all three species can be easily distinguished from *Cliona celata* with the naked eye. *Cliona celata* excavates large tunnels in the shell and the other three make much smaller tunnels. The holes made by *C. celata* are approximately 1.5 to 2.5 mm in diameter when occupied by living sponges. and become larger after the sponge dies. The holes made by the other species are usually only 0.2 to 0.5 mm in diameter, and never more than half as large as those made by *C. celata.*

After microscopic study had shown that *C. truitti* and *C. celata* were the common species and that *C. lobata* and *C. vastifica* were rare in the bays under study, identifications of *Cliona celata* and of "*truitti*-type *Cliona*" were often made in the field, on the basis of the size of the excavations. Incidentally, published photographs show that oyster biologists have occasionally mistaken the burrows of the boring clam *Martesia smithii* and the boring worm *Polydora websteri* for the excavations of *Cliona celata,* but such mistakes can easily be avoided.

The Species of *Cliona* and Their Geographic Distribution

Cliona celata Grant, 1826, is the "sulphur sponge" of the oyster biologists. *Cliona sulphurea* (Desor, 1848) is one of its synonyms. The common name refers to the bright sulphur yellow color. It is a true marine species which extends into only the lower or more saline portions of bays. In the ocean or in the open Gulf *C. celata* is often found in the "massive" form, which may be several inches high. In Louisiana and Texas bays it may form a yellow crust over shells, but usually is seen as a number of bright yellow or greenish-yellow papillae projecting from holes in a shell which it has honeycombed with tunnels. The entrances of the tunnels are 1.5 to 2.5 mm in diameter. Microscopically, *C. celata* is distinguished by the large size of the tylostyles, 220 to 400 micra long and 4 to 10 micra wide, and the

absence of oxeae (amphioxi). Some specimens have minute spirasters similar to those of *C. truitti,* although no spirasters were seen by Old. *Cliona celata* is a cosmopolitan species, reliably reported from most of the European coasts (Scandinavia to Italy), from India (Bay of Bengal and Gulf of Manaar, fidé Annandale, 1915), and from California (fidé de Laubenfels, 1932), as well as all along the Atlantic coast of North America from Prince Edward Island and Nova Scotia to South Carolina. If *Cliona caribboea* Carter, 1882, is a variety of *C. celata,* as its spiculation suggests, the Florida keys, the West Indies, and Panama would be added to its known range. Old (1941) found *C. celata* in Chesapeake Bay only up as far as Tangier Sound on the Maryland-Virginia boundary, and only where the salinity was 15.75 parts per thousand or higher at the time of collection. Pearse and Wharton (1938) did not find *C. celata* in Apalachicola Bay, Florida. Moore (1899) reported a boring sponge "closely related to, if not identical with, the *Cliona sulphurea,*" on oyster reefs in lower Barataria Bay. Under the name of this synonym, *C. celata* was reported from a number of Louisiana bays in bulletins of the old Gulf Biologic Station, 1904-1910.

Cliona lobata Hancock, 1948, is easily distinguished from *C. celata* by the smaller size of its galleries and of the papillae projecting from the holes on the surface of the shell. Microscopically, it is easily distinguished from all other species by the absence of oxeae (amphioxi) and by the large size of the sharply spiral or zigzag spirasters. The spirasters are 15 to 50 micra long and have comparatively large spines at the angles. The tylostyles are similar to those of *C. vastifica* and *C. truitti* in size and shape. *Cliona lobata* has been reported by specialists from Sweden (Alander, 1942, found it from low-water level to 1265 meters depth) and elsewhere in the North Sea and connecting waters, and from both the Atlantic and the Mediterranean coast of France. De Laubenfels (1954, 1955) has recently found this species in the Gilbert and Marshall Islands of the Pacific. In North America, Old (1941) reported *C. lobata* from Long Island, from bays connecting with the ocean on the sea side of the Eastern Shore of Maryland and Virginia, from Beaufort, North Carolina, and from lower Chesapeake Bay up as far as Kedges Strait in Maryland, just above the Virginia line on the eastern side of the bay. It is listed along with *C. celata* on the California coast by Smith *et al* (1954). Apparently all of the waters where *C. lobata* has been found are within the salinity range of *C. celata. Cliona lobata* has not been reported

from the Gulf coast previously, so far as the writer can discover.

Cliona vastifica Hancock, 1849, is another of the "small species," making holes and galleries only 0.2 to 0.5 mm in diameter. The papillae are sometimes yellowish and sometimes red. Microscopically, this species is distinguished by its small tylostyles (160 to 250 micra long and 3 to 5 micra wide), its finely spined oxeae (amphioxi), and its short, stout, zigzag spirasters with fine spines, more prominent at the angles. This species is more estuarine or euryhaline than *C. celata* and is reported from some places where *C. celata* does not occur. According to Annandale (1915) *C. vastifica* is the only boring sponge in Chilka Lake, where it survives through periods of practically fresh water, and is the commonest species in all estuarine and shallow littoral waters of India. It was the only species of boring sponge found at Bimini, Western Bahamas, and at Kaneohe Bay, Oahu, by de Laubenfels (1949, 1950), and the only species found in Apalachicola Bay, Florida, by Pearse and Wharton (1938). *Cliona vastifica* has been reported also from Norway, Sweden, Denmark, England, Belgium, all of the coasts of France (English Channel, Atlantic, and Mediterranean), Adriatic Sea, Black Sea, Indian Ocean, Japan, and New Zealand. It had been found in the Gulf of Mexico prior to 1887, according to Topsent. Old (1941) found *C. vastifica* in Long Island Sound, in the harbor of Beaufort, North Carolina, and in York River, Virginia. Lunz (1935) reported it from South Carolina oyster beds, where it was much less common than *C. celata*. Wells and Old (1937) reported that the highest percentage of infestation of oysters by *C. vastifica* occurred in the salinity range 11 to 13 parts per mille, and that 10 was the lowest salinity in which *C. vastifica* was found. However, these records refer to the work done in 1935, before *C. truitti* was recognized as distinct from *C. vastifica;* in 1941 Old did not list any Maryland locations for *C. vastifica*.

Cliona truitti Old, 1941, was reported by its describer from Long Island Sound and from many localities in Maryland, including tributaries (Choptank River, Patuxent River, Potomac River, St. Mary's River, Wicomico River) as well as the Chesapeake Bay itself, and Sinnepuxent Bay on the sea coast of Maryland. Frey (1946) found living specimens of *C. truitti* as far upstream as Sheepshead Bar in the Potomac River, and shells bored by *C. truitti* were found even farther up the river. The salinity at Sheepshead Bar is as low as 6 parts per thousand in spring, but is as high as 18 in autumn, according to the records reported by Frey. *Cliona truitti* is very similar to *C. vastifica*,

and shares with it the power to reproduce asexually by means of gemmules. Gemmule formation may be the main factor in permitting these species to extend their ranges into estuaries where the salinity gets low enough to kill other species of *Cliona*. *C. truitti* is distinguished from *C. vastifica* mainly by the smaller size and different shape of spirasters, which are nearly straight in *C. truitti* and definitely zigzag in *C. vastifica*. Topsent (1932) described and pictured a "brackish water form of *Cliona vastifica* with modified spiculation" from L'Oued Melah, Tunisia, which seems to be identical with *C. truitti*. Another brackish-water form which appears from the illustrations to be very similar to *C. truitti* is *C. stationis* Nassonov, 1883, from the Bay of Sebastopol, Russia, and from the Gudaut oyster bank on the Black Sea coast of Georgia (fidé Nikitin, 1934).

The records on geographical distribution of the species of *Cliona*, unless otherwise indicated, are from the monographs of Topsent (1887, 1900).

TABLE 1

SPECIMENS OF *Cliona* IDENTIFIED BY MICROSCOPIC EXAMINATION, 1948

Source of Sample	Date	Species of *Cliona*			
		celata	*lobata*	*vastifica*	*truitti*
California Point seed oysters	6/30	0	0	0	11
Same, in trays, Bayou Scofield	9/10	0	0	0	19
Same, in trays, Bay Coquette	9/10	1	0	0	19
Bayou Wilkinson & Bay Chene Fleur	12/10	0	0	0	2
Bayou Rigaud, Lower Barataria B.	12/8	5	0	0	18
Sugar House Bend, Lower Barataria B.	8/28 & 12/6	3	1	0	8
Oyster Bayou, Terrebonne Parish	9/22	0	0	0	10
Lake Barre, tray oysters	8/30	7	1	1	10
Bay Ste. Elaine, native oysters	8/30 & 12/15	8	4	2	9
Caillou Island, tray oysters	8/30	7	0	0	2
Total all samples (148 specimens)		31	6	3	108

THE DISTRIBUTION OF *Cliona* SPECIES IN LOUISIANA, IN RELATION TO SALINITY

Table 1 shows the results of microscopic examination of *Cliona* specimens from oyster shells collected in several Louisiana localities.

The California Point seed oysters, dredged from natural reefs east of the Mississippi River, were mostly 2 to 3 inches long and approximately one year old. Only 10 per cent of them had any kind of boring sponge, and the only species present was *Cliona truitti*. The oysters were placed in trays in Bayou Scofield, Bay Coquette, and several other water bodies in what we called the "Buras area," that is, the

marshland of lower Plaquemines Parish just west of the Mississippi River. By December 9, 1948, *Cliona truitti* had increased in most of the trays, but only 2 specimens of *Cliona celata* could be found in several hundreds of oysters and shells which were carefully examined by naked eye. In Bay Tambour, which had lower salinity than the other "Buras area" bays because of an indirect connection with the river, *Cliona truitti* eventually died out.

The station at the junction of Bayou Wilkinson and Bay Chene Fleur, on the east side of the upper end of Barataria Bay, was at the extreme limit of the range of *Cliona truitti*. It was sometimes necessary to examine several hundreds of oysters in order to find one with *Cliona truitti,* and the incidence was never more than about 2 per cent.

The Bayou Rigaud and Sugar House Bend stations were at the lower end of Barataria Bay, on the west and the east sides, respectively, of Barataria Pass which connects the bay with the Gulf. *Cliona celata* was abundant at these stations, especially in very old oysters and in dead shells, but *Cliona truitti* was much more abundant.

Oyster Bayou and Bayou Bas Bleu are twin bayous running side by side from Lake Tambour (in Terrebonne Parish) to Lake Barre. A salinity station was maintained in Bayou Bas Bleu from September 1947 through February 1949. The 10 oysters examined microscopically had been taken from Oyster Bayou on September 22 and kept in trays in Bay Sainte Elaine until December 11, 1948, when they were examined. No *Cliona celata* was found in these trays even after the oysters had lived 2½ months in Bay Sainte Elaine water. However, some *C. celata* was seen in both bayous, mostly in very old native oysters and in dead shells. *Cliona truitti* was the dominant form and was very abundant, although some oysters, even fairly old ones, were free of any kind of boring sponge.

Lake Barre and Bay Sainte Elaine are small water bodies connecting with Terrebonne Bay. The Lake Barre station was at the lower end of the "lake" near the connection with Terrebonne Bay, and the Bay Sainte Elaine station was in the "pass" which connects this bay with Bay Coon Road. The two stations were very similar in their faunas, including the species of *Cliona;* practically every old oyster and dead shell was infested with boring sponge; *C. celata* and *C. truitti* were equally abundant; *C. lobata* and *C. vastifica* were also present, but in much less abundance.

Caillou Island is near the lower end of Terrebonne Bay and is close

to two "passes" which connect the bay with the Gulf. No continuous salinity studies were made at this station, but spot samples taken at irregular intervals indicated that the salinity was higher than at Bay Sainte Elaine and Lake Barre, as would be expected from the location. *Cliona celata* was very abundant in all old oysters and shells below mean low water level, and *Cliona truitti* was present in less abundance. Microscopic examination of a larger sample would probably have shown *C. lobata* and *C. vastifica* to be present also.

On the basis of laboratory and field notes on *Cliona* in oysters and shells, the writer has attempted to classify the estuarine waters of Louisiana into 6 "*Cliona* zones" as follows:

Zone 0. No boring sponge of any kind, although oysters may be present in abundance. Examples are Bayou Tambour inland from Lake Tambour in Terrebonne Parish, and Bayou Chicot, a connecting bayou still farther inland. Unfortunately there are no salinity records for these waters, except a few spot samples which show them to have lower salinity than Bayou Bas Bleu. On Dec. 9, 1947, when the salinity in Bayou Bas Bleu was 17.3 to 18.4, the salinity in Bayou Tambour was 8.9 to 13.1 and that in Bayou Chicot was 6.8 to 8.6 parts per thousand. Large populations of native oysters flourish in both bayous.

Zone 1. *Cliona truitti* rare, and *C. celata* completely absent. Bay Chene Fleur and Bayou Wilkinson in Jefferson Parish, and the upper end of Lake Felicity in Terrebonne Parish, are examples. *C. truitti* was found in less than 5 per cent of the oysters collected in the upper end of Lake Felicity on August 10, 1951.

Zone 2. *Cliona truitti* abundant, present in most of the older oysters; *C. celata* relatively scarce, confined mostly to very old oysters and dead shells, and sometimes represented only by old borings in which no live sponge is found. Such Terrebonne Parish locations as Bayou Petite Caillou near Cocodrie, Bayou Terrebonne, Oyster Bayou, and Bayou Bas Bleu belong in this zone, as do most of the bays and bayous of the "Buras area" on the west side of lower Plaquemines Parish.

Zone 3. *Cliona truitti* the dominant species of boring sponge, much more abundant than *C. celata,* but *C. celata* also common. Lower Barataria Bay and the lower end of Lake Felicity are in this zone. *C. vastifica* and *C. lobata* may be found in this zone, but only rarely.

Zone 4. *Cliona truitti* and *C. celata* both abundant, about equally numerous in living oysters, as at Lake Barre and Bay Sainte Elaine. *Cliona celata* may be more abundant than *C. truitti* in very old oysters

and in old shells. *C. lobata* and *C. vastifica* are also found in Zone 4.

Zone 5. *Cliona celata* more abundant than *C. truitti,* as at Caillou Island. Other parts of lower Terrebonne Bay and lower Lake Pelto are also in this zone. No oysters, or very few oysters, live to the age of one year below mean low water level in Zone 5. *Cliona* is found in the shells of dead oysters below low tide level, not in the live oysters of the intertidal zone.

TABLE 2

SALINITY RANGES IN FOUR ZONES CLASSIFIED ACCORDING TO THE ABUNDANCE OF *Cliona Truitti* AND *Cliona Celata*
(salinity in parts per thousand)

Month, Year	Zone 1 B. Chene Fleur	Zone 2 Buras Area	Zone 2 B. Bas Bleu	Zone 3 L. Barataria B.	Zone 4 Lake Barre	Zone 4 B. Ste. Elaine
Sept. '47	9-19		10-29	19-30	21-29	
Oct. '47	11-25		7-17	23-30	22-28	
Nov. '47	6-22			9-31	20-32	
Dec. '47	3-22	15-31		4-29	15-26	
Jan. '48	4-17	15-33	10-23	12-29	17-26	
Feb. '48	5-19	5-28	10-26	12-31	20-30	21-26
Mar. '48	1-24	6-20	8-24	1-25	13-27	15-25
Apr. '48	1-9	7-15	9-19	5-25	13-25	16-23
May '48	3-9	10-21	16-21	11-30	15-22	19-22
June '48	5-18	9-27	16-25	15-35	17-28	22-25
July '48	12-20	14-24	19-26	18-36	21-26	17-25
Aug. '48	7-15	11-21	12-23	14-30		16-24
Sept. '48	1-18[a]		7-17	6-29		13-23
Oct. '48	2-28[a]	18-30	11-23	10-36		18-25
Nov. '48	1-31[a]	10-30	6-23	2-33		16-25
Dec. '48		11-24	7-21	5-31		16-20

[a]The Bay Chene Fleur salinity station was discontinued at the end of August, 1948; the records for Sept.-Nov., 1948 are from St. Mary's Point, in the upper end of Barataria Bay.

Table 2 shows some 1947-1948 records of salinity ranges at 6 stations representing "*Cliona* zones" 1, 2, 3, and 4. Table 3 shows the most frequent salinity for each month of the year at Bay Chene Fleur (Zone 1), Lower Barataria Bay Station 51 (Zone 3), and Bay Sainte Elaine (Zone 4). Over a one year period, September 1947 through August 1948, the most frequent salinity at Bay Chene Fleur was 6 and the most frequent at Station 51 (Lower Barataria Bay) was 27. However, in the next 12-month period the most frequent salinity at the lower bay station was 17, a full 10 parts lower than in 1947-48. The most frequent salinity at Bay Sainte Elaine was 21

TABLE 3
MOST FREQUENT SALINITY IN EACH CALENDAR MONTH AT 3 STATIONS

Based on hourly readings by conductivity at Bay Chene Fleur and Lower Barataria Bay, and on titrations of samples taken daily at 7 a.m at Bay Sainte Elaine. Salinity in parts per thousand.

Month[a]	Zone 1 Chene Fleur	Zone 3 Lower Barataria	Zone 4 Ste. Elaine
January	6	25	21[c]
February	9	23	23
March	2	16	17
April	3	13	19
May	6	16	21
June	15	26	23
July	16	22	23
August	12	23	21
September	13[b]	22	15
October	19[b]	23	22
November	17[b]	27	22
December	4[b]	19	19

[a]All months in 1948 except those marked *b*, which are for 1947, and the one marked *c*, which is for 1949.

in the 12-month period February 1948 through January 1949.

The comparisons of salinity ranges and of most frequent salinities do not seem to show a clear-cut difference between Zones 3 and 4, as the differences in the *Cliona* fauna would indicate. However, when the percentages of days in low and high salinity are compared, as in Table 4, a distinct difference is evident. Salinity measurements at Bay Sainte Elaine were based on samples taken daily at 7 a.m., so the other stations were compared on the basis of 7 a.m. measurements.

TABLE 4
PERCENTAGE OF DAYS IN ONE YEAR PERIOD IN EACH OF 7 SALINITY RANGES AT 5 STATIONS IN LOUISIANA

Location of Station	*"Cliona* Zone"	Salinity in Parts per Thousand at 7 a.m. 0-4.9	5-9.9	10-14.9	15-19.9	20-24.9	25-29.9	30+
Bay Chene Fleur	1	15	31	30	22	2	0	0
Bayou Bas Bleu	2	0	4	28	41	27	0	0
L. Barataria Bay	3	1.5	4.5	4	25	34	25	6
Bay Ste. Elaine	4	0	0	2	35	60	3	0
Lake Barre	4	0	0	1.5	24	46	28.5	0

At Bay Chene Fleur (Zone 1), the salinity at 7 a.m. was below 15 on 76 per cent of the days in the year, below 10 on 46 per cent of the days, and below 5 on 15 per cent. At Bayou Bas Bleu (Zone 2), the salinity was below 15 on 32 per cent of the days, and below 10 on 4 per cent. At the Lower Barataria Bay station (Zone 3), the salinity was below 15 on 10 per cent of the days, below 10 on 6 per cent, and below 5 on 1.5 per cent, while the Zone 4 stations, Bay Sainte Elaine and Lake Barre, never had salinities below 10 parts per thousand. Recordings of salinity made by a conductivity apparatus at Lake Barre, continuously every day for 11 months, failed to show any readings as low as 10 at any time. It is probable that *Cliona celata* becomes more abundant in Zone 4 because of the absence of the periods of extremely low salinity which occur in Zone 3. As noted earlier, Old failed to find any *Cliona celata* in Chesapeake Bay at points where the salinity was below 15. At Bay Sainte Elaine and Lake Barre, salinities below 15 occurred on only 1 to 2 per cent of the days. In Zone 5, where *Cliona celata* is the dominant species of boring sponge, the salinity probably never drops below 15 and seldom below 20 parts. There is no evidence that *C. truitti* is affected unfavorably by the higher salinity, but it is probably unable to compete successfully with *C. celata* where the salinity is favorable for rapid growth and reproduction of the more robust species.

No microscopic examination of *Cliona* specimens from Texas has been made. In 1949, both *Cliona celata* and one or more smaller species (making tunnels of the size characteristic of *C. truitti, C. lobata,* or *C. vastifica*) were very common in oysters and shells examined by naked eye in Aransas Bay, Mesquite Bay, and Copano Bay, Texas. It was not practical to draw any conclusions as to the zonation of the *Cliona* species in Texas, because the salinity conditions on this coast have been abnormal for several years due to drought. Copano Bay is an "inside bay" which normally has low salinity during at least part of the year, averaging 7.9 during the period June 1941 to January 1942, while the average salinity for June 1949 to January 1950 was 19.6 parts per thousand. These salinity figures were furnished by Dr. Gordon Gunter of the Institute of Marine Science at Port Aransas, Texas.

Invasion of Oyster Shells by *Cliona*

Nassonov (1883, 1924), working on *Cliona stationis* at Sebasto-

pol, studied the setting of larvae and the beginning of the boring process in young sponges. Wells and Old (1937) found no boring sponges in oysters growing on anchor-chains of war-surplus ships moored in Patuxent River. They therefore expressed doubt that infestation of oysters by planktonic larvae of *Cliona* was effective in Maryland waters. Old did not mention any observations on setting of larvae or on the details of the boring process in his 1941 paper, but did give a brief account of such studies in 1942. The 1942 paper was read at the annual meeting of the National Shellfisheries Association, but was never published. An extract from Old's 1942 paper was reproduced by Ladd (1943). Evidently Old repeated and confirmed Nassonov's observations on the setting of *Cliona* larvae and the initiation of boring. He did not state what species was studied, but reported that in the Chesapeake Bay at Solomons, Maryland, eggs were found in boring sponges "beginning about August 1st," and "clean pieces of shell or calcite received a set of larvae as early as July 28th."

In Louisiana, young oysters, less than one year old, seldom have any *Cliona* in the right valve. Many do have the left or attached valve invaded by *Cliona* from the old "cultch" shell to which the young oyster is attached. Oysters between one and two years old usually have sponge only in the left valve and the older part of the right valve, around the umbo and hinge. Even oysters two to three years old have more *Cliona* tunnels in the left valve than in the right one. The oysters which have both valves thoroughly honeycombed by boring sponge are usually four or five years old, which is very old for Louisiana oysters.

On the basis of these observations, it seems probable that most *Cliona*-infested oysters in Louisiana obtained the infestation directly from the old oysters or shells to which the spat were originally attached. However, in "*Cliona* Zone 4" the author has frequently found one species in the left valve and older part of the right valve, and a different species in the younger part of the right valve. In these cases, the second species probably grew from planktonic larvae which set on the exposed surfaces of the right valve. Occasionally small patches of two and even three different species of *Cliona* have been found in the right valve of an old oyster.

When oysters are transferred from a low salinity zone to a higher salinity, their *Cliona* fauna changes only slowly, over a period of

months. Native oysters from Oyster Bayou, moved to Bay Sainte Elaine in September, still contained only *Cliona truitti* after 2½ months. Bay Chene Fleur oysters, almost completely free of any kind of boring sponge, were moved to several stations in the "Buras area" in August; they did not show any *Cliona* until October, and even in March (7 months after the transfer) only 5% showed "severe" *Cliona* infestations. Bay Chene Fleur oysters moved in December to Bayou Rigaud in lower Barataria Bay did not pick up any boring sponge until the following summer; in July, 7 months after the transfer, about 7% of these oysters had *Cliona* infestations; by the following July, 19 months after the transfer, practically 100% were infested by *Cliona* (mostly *C. truitti,* but some *C. celata*). On the other hand, oysters moved from *Cliona*-free territory to lower Barataria Bay in summer developed many heavy infestations during the first year. Notes on several series of such transfers indicate that new infestations, originating from planktonic larvae, begin in summer or in early autumn, but not in winter or early spring when the water is cold.

It follows from the above notes that only the *Cliona* in oysters known to have been *in situ* for at least one year can be used in studies of the salinity regime. It is also evident that the *Cliona* fauna of a locality indicates the long-term salinity regime of the local waters, and not just the recent salinity.

Summary and Discussion

It has been stated in this paper that the species of *Cliona* may be used as salinity indicators, and that Louisiana estuarine waters may be marked off in six zones (0, 1, 2, 3, 4, and 5) on the basis of the presence or absence and the relative abundance of *Cliona celata* and *Cliona truitti*. These zones apparently do not correspond with differences in salinity range, in mean salinity, or in most frequent salinity, but they do correspond with differences in frequence of extremely low salinity, as shown in Table 4. It is tentatively suggested that the absence of *Cliona celata* indicates that the salinity is below 10 parts per thousand approximately one-fourth of the time and below 15 approximately half the time. The absence of *Cliona truitti* indicates that the salinity is probably below 10 at least half the time. *Cliona celata* becomes more abundant than *C. truitti* only in waters of relatively stable salinity, with few or no readings below 15. More exact statements of correlations of *Cliona* abundance with salinity readings must await further study. It is the purpose of this paper to show that further study

of the *Cliona* species as salinity indicators is needed, and that valuable information may be expected from such a study.

As a biologist, the author is not so much interested in the correlation of *Cliona* distribution with salinity figures as in the correlation of the *Cliona* fauna with ecological complexes. The author's observations, and those of his colleagues in Louisiana oyster investigations, indicate that "*Cliona* Zone 0" is free or almost free of the important oyster parasite *Dermocystidium marinum* Mackin, Owen, and Collier; that the upper (inland) limit of the predaceous snail *Thais haemastoma* lies in "*Cliona* Zone 2"; that zones 0, 1, and 2 are characterized by predominantly subtidal oyster populations; that oysters never live below low tide level in Zone 5; and that zones 3 and 4 are transitional in this respect, with some oysters above and some below low tide level, the subtidal populations surviving (if they survive at all) in spite of a very high summer mortality caused by parasites and predators. The populations of other molluscs (*Congeria leucopheata, Brachidontes recurvus, Rangia cuneata, Martesia smithii, Neritina reclivata*) and crustaceans (barnacles, Xanthid crabs, etc.) also show definite correlations with the *Cliona* zones.

The siliceous spicules of boring sponges are almost indestructible. The species can be identified from fragments of old shells as easily as from living specimens. A study of the species of *Cliona* in old buried oyster reefs and fossil shell beds might add to a knowledge of ecological conditions in ancient times. Knowledge of the salinity relations of the living species could probably be applied directly to a study of the Pleistocene and early Post-Pleistocene shell deposits, and might shed much light on climatic and topographic changes during the periods the molluscs lived.

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THE OCCURRENCE AND TAXONOMIC RELATIONSHIPS OF THE BLUE MARLIN (*MAKAIRA AMPLA* POEY) IN THE PACIFIC OCEAN[1]

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ABSTRACT

Evidence is presented indicating that the Atlantic blue marlin also occurs in the Eastern Pacific Ocean. Such evidence includes direct comparison of specimens from both oceans on the basis of quantitative and qualitative characters. The taxonomic relationships of the blue marlin in the eastern Pacific, are established by direct comparison with the black and striped marlins from the same geographical region. In addition, the occurrence of the blue marlin throughout the central and western Pacific is established by discussion of the pertinent literature.

INTRODUCTION

Studies conducted by the author during the past three years in Acapulco, Mexico and the Gulf of Panama, have confirmed the suspected occurrence of the Atlantic blue marlin (*Makaira ampla* Poey, 1860) in the Pacific Ocean. As a result of this, a study of the literature has also shown that several nominal species and other records of marlin proposed in the past from various parts of the Pacific refer to this form, whose occurrence throughout that ocean had never been established. In a recently published review of the marlins (*Makaira*), La Monte (1955) variously refers to the unconfirmed occurrence of the blue marlin in the Pacific Ocean, but offers no comment or supporting evidence.

In the present study, the above conclusions are demonstrated by comparison of specimens from the Atlantic and Pacific oceans and a discussion of the pertinent literature. In addition, the validity of *Makaira ampla* as a distinct species and its relationships with the other Pacific marlins are established by comparison with specimens of *M. marlina* Jordan and Hill, 1926, (black marlin) and *M. mitsukurii* Jordan and Snyder, 1901, (striped marlin) from the same geographical area.

[1]Contribution No. 153 from the Marine Laboratory, University of Miami. This constitutes a technical report to the Charles F. Johnson Foundation.

This paper is the result of investigations conducted through a research fellowship made available to the University of Miami Marine Laboratory by the Charles F. Johnson Foundation. Thanks are also due to Mr. Louis E. Marron for additional financial aid and to Messrs. John K. Howard, Al Pflueger, Willard C. Brown, Thomas O'Connor and Captain Ed Moore and Walter Gorman for their cooperation during the field work.

TABLE 1. — Body length, locality and date of collection of specimens of *Makaira ampla, M. marlina* and *M. mitsukurii* used in the present study.

Makaira ampla

Specimen No.	Length (mm)	Locality	Date
1	1793	Acapulco, Mexico	February 4, 1954
2	2500	Acapulco, Mexico	February 5, 1954
3	2340	Acapulco, Mexico	February 7, 1954
4	2112	Sombrero Key, Florida	March 3, 1954
9	2160	Miami, Florida	April 24, 1954
11	2280	Bimini, Bahamas	April 24, 1954
12	1773	Bimini, Bahamas	April 28, 1954
16	2360	Cat Cay, Bahamas	March 10, 1955
18	2450	Cat Cay, Bahamas	March 19, 1955
20	2680	Bimini, Bahamas	June 1, 1955
22	2580	Piñas Bay, Panama	July 18, 1955
23	2330	Cat Cay, Bahamas	July 21, 1955
24	2430	Cat Cay, Bahamas	July 26, 1955
25	2465	Cape Hatteras, N. Carolina	August 21, 1955

Makaira marlina

Specimen No.	Length (mm)	Locality	Date
1	2420	Piñas Bay, Panama	July 14, 1953
3	2370	Piñas Bay, Panama	July 16, 1953
4	2290	Acapulco, Mexico	February 3, 1954
5	2207	Acapulco, Mexico	February 6, 1954
6	2130	Acapulco, Mexico	February 7, 1954
7	1796	Acapulco, Mexico	February 7, 1954
14	2850	Cabo Blanco, Peru	August 13, 1954
17	2755	Cabo Blanco, Peru	August 14, 1954
26	2070	Piñas Bay, Panama	July 17, 1955
27	2175	Piñas Bay, Panama	July 20, 1955

Makaira mitsukurii

Specimen No.	Length (mm)	Locality	Date
1	2160	Acapulco, Mexico	January 29, 1954
2	2250	Acapulco, Mexico	February 2, 1954
3	2330	Acapulco, Mexico	February 9, 1954
4	2625	Iquique, Chile	June 8, 1954
5	2506	Iquique, Chile	June 11, 1954
6	2325	Iquique, Chile	June 11, 1954
7	2440	Arica, Chile	June 21, 1954
8	2667	Iquique, Chile	July 6, 1954
9	2430	Piñas Bay, Panama	July 14, 1955

Materials and Methods

The present study is based on fresh-caught material captured by anglers (Table 1) and comprising 14 specimens of *Makaira ampla* from the western Atlantic and eastern Pacific, 10 specimens of *M. marlina* from the eastern Pacific, and 9 specimens of *M. mitsukurii* from the eastern Pacific. In addition to measurements and counts, dissections and observations on coloration and other qualitative characters were also conducted in the field.

Measurements and counts were made according to the method recently proposed by the writer (Rivas, 1956). Proportions are expressed in thousandths of the body length and specimens of about the same length range and mean length were purposely used for the three species in order to avoid possible errors due to allometry. No significant allometric changes were observed for any of the characters, within the length ranges considered in the present paper.

Comparison of Atlantic and Pacific Specimens

A comparison of eastern Pacific specimens with Atlantic specimens of *Makaira ampla* shows that both samples belong to the same species and establishes the occurrence of the blue marlin in the Pacific Ocean, as discussed below.

Morphometric and meristic comparison (Table 2) on the basis of 42 proportions and five counts shows that both samples are identical, with the exception of the prepectoral and prepelvic length, depth of body at origin of first anal, width of body at origin of second anal, bill length and number of dorsal and anal spines.

The average morphometric differences referred to above, however, are very small and some of them may not be found to be significant when a larger sample from the Pacific is available for comparison. Characters relating to depth and width of the body may be expected to be subjected to seasonal variations due to spawning and feeding and are therefore unreliable. The length of the bill is also known to be an unreliable character as shown by its great variability (Table 2), since this organ is frequently malformed or its tip broken (LaMonte, 1955: 328, 329; Rivas, 1955). The prepectoral and prepelvic length, however, appear to be slightly longer in the Atlantic sample and this correlation may be an indication that the pectoral and pelvic girdles are placed somewhat further forward in the Pacific blue marlin.

As to the meristic differences, the central position of the mean for

TABLE 2 — Comparison between blue marlin *(Makaira ampla)* of similar length, from the western Atlantic and the eastern Pacific. Proportions are expressed in thousandths of the body length.

	Western Atlantic		Eastern Pacific	
	Range	Mean	Range	Mean
Number of specimens	10		4	
Body length in millimeters	1773-2680	2304	1793-2580	2303
First predorsal length	206-227	216	210-224	217
Second predorsal length	761-776	772	762-785	771
Prepectoral length	229-249	234	221-235	227
Prepelvic length	232-260	245	230-242	238
First preanal length	554-579	562	558-568	563
Second preanal length	752-772	758	757-767	762
Origin first dorsal to origin pectoral	140-166	154	142-166	155
Origin first dorsal to origin pelvic	175-197	185	178-199	185
Origin second dorsal to origin second anal	105-119	111	99-123	107
Origin of pelvic to nape	160-184	170	162-169	166
Greatest depth of body	196-219	202	183-225	202
Depth of body at origin first dorsal	172-194	181	174-195	181
Depth body at origin first anal	162-190	173	142-187	161
Least depth of caudal peduncle	36-42	39	37-44	40
Width body at origin pectoral	90-100	97	87-104	94
Width body at origin first anal	95-117	106	93-107	102
Width body at origin second anal	69-81	78	52-75	66
Width of caudal peduncle	44-55	50	50-54	52
Length of upper caudal keel	35-44	40	38-53	44
Length of lower caudal keel	32-39	36	36-45	39
Head length	227-240	233	229-240	234
Snout length	96-105	101	94-103	100
Bill length	260-284	272	238-280	265
Maxillary length	137-148	144	134-146	141
Orbit diameter	22-30	27	24-27	26
Interorbital width	69-76	72	68-77	72
Depth of bill	11-16	13	10-15	13
Width of bill	15-20	17	15-20	18
Origin first dorsal to edge of fin	94-110	103	96-121	107
Length of second dorsal base	42-55	49	47-56	50
Length of first anal base	149-174	163	168-174	171
Length of second anal base	48-56	52	45-52	50
Anterior height of first dorsal	145-171	159	150-165	155
Anterior height of second dorsal	33-49	42	36-47	42
Height of first anal	123-142	134	122-146	135
Anterior height of second anal	24-37	32	28-36	33
Length of pectoral	195-223	210	200-216	210
Length of pelvic	133-194	166	135-215	170
Length of second dorsal	98-119	110	101-123	113
Length of second anal	98-118	108	100-116	108
Length of upper caudal lobe	252-276	268	252-300	270
Length of lower caudal lobe	236-272	255	242-289	260
Dorsal spines	39-44	41.4	41-45	42.8
Dorsal rays	6-7	6.5	6-7	6.8
Anal spines	14-16	15.1	16-17	16.5
Anal rays	6-7	6.7	6-7	6.8
Pectoral rays	20-22	21.3	21-22	21.5

the dorsal and anal spines in both samples, would seem to indicate that the Pacific population has an average of one or two more dorsal and anal spines.

As would be expected from the similarity in morphometric characters, there was no observable difference in external appearance between the Atlantic and Pacific specimens. The body form, as already described for the Atlantic blue marlin (Conrad and LaMonte, 1937, fig. 1; Gregory and Conrad, 1939, fig. 1) was the same in both samples, as well as the color pattern which presented in the Pacific specimens the same wide range of variation observed for the species in the Atlantic (Conrad and LaMonte, 1937: 207; LaMonte, 1955: 344).

Unlike other species of marlin, *Makaira ampla* does not possess a visible, simple lateral line running along the middle of the sides of the body. Instead, the lateral line is inconspicuous, complex, and forms a reticulate pattern covering the sides of the body. It is faintly visible only when the skin is dry or by translucency when a patch of skin is removed and held up to the light. Both Atlantic and Pacific specimens were found to be similar in this character.

Another character not previously observed in billfishes, is the presence in some species of a median, longitudinal ridge in the region of the isthmus, with a groove on each side extending anteriorly to the cleithrum. This structure was present and conspicuous in the Atlantic and Pacific specimens and is now known to be absent in the black marlin (*Makaira marlina*).

In both the Atlantic and Pacific samples the pectoral fin was not rigid and could easily be folded back, flat against the sides of the body without breaking the joint. Attention is called to this structural condition, since in the black marlin (*Makaira marlina*) with which *M. ampla* has been confused in the Pacific, the pectoral fin is rigid and cannot be folded back against the body without breaking the joint (Gregory and Conrad, 1939: 453, 454; Nakamura, 1952: 62, 63; 1954: 37; 1955: 10; LaMonte, 1955: 337).

There is reason to believe that the blue marlin occurs throughout the tropical and subtropical regions of the Atlantic, Indian and Pacific Oceans, and that the western Atlantic and eastern Pacific populations represent the end points of a more or less continuous clinal distribution all around the world. Mean morphometric and meristic differences such as those discussed above are expected to occur between isolated

TABLE 3.—Comparison of blue marlin (*Makaira ampla*) with black marlin (*Makaira marlina*) and striped marlin (*Makaira mitsukurii*) of similar length from the Eastern Pacific. The data for *Makaira ampla* includes the specimens from the Western Atlantic and the Eastern Pacific compared in Table 1. Proportions are expressed in thousandths of the body length. Absolute differences between *M. ampla* and each of the other two species are indicated by solid lines. Average differences are indicated by dotted lines.

	Makaira marlina		Makaira ampla		Makaira mitsukurii	
	Range	Mean	Range	Mean	Range	Mean
Number of specimens	10		14		9	
Body length in millimeters	1796—2850	2306	1773—2680	2304	2160—2667	2415
First predorsal length	204—234	220	206—227	216	227—259	241
Second predorsal length	757—790	773	761—785	772	791—810	799
Prepectoral length	230—256	246	221—249	232	256—274	264
Prepelvic length	260—282	272	230—260	243	272—292	279
First preanal length	578—611	597	554—579	562	596—616	607
Second preanal length	771—783	777	752—772	759	781—799	792
Origin first dorsal to origin pectoral	170—188	178	140—166	154	129—151	141
Origin first dorsal to origin pelvic	203—226	210	175—199	185	160—181	171
Origin second dorsal to origin second anal	112—133	123	99—123	110	88—105	99
Origin of pelvic to nape	189—199	195	160—184	169	157—171	166
Greatest depth of body	213—240	226	183—225	202	165—193	178
Depth of body at origin first dorsal	188—216	200	172—195	181	155—177	165
Depth of body at origin first anal	156—200	180	142—190	170	124—154	137
Least depth of caudal peduncle	35—44	41	36—44	39	39—43	40
Width body at origin pectoral	88—106	97	87—104	96	73—88	80
Width body at origin first anal	88—106	99	93—117	105	73—95	83
Width body at origin second anal	68—77	73	52—81	74	57—73	66
Width of caudal peduncle	48—69	62	44—55	50	42—49	46
Length of upper caudal keel	40—46	43	35—53	41	30—37	34

Length of lower caudal keel	33—44	38	32—45	37	29—35	32
Head length	241—268	254	227—240	233	254—273	263
Snout length	112—130	119	94—105	101	125—138	130
Bill length	260—298	276	238—284	269	254—304	272
Maxillary length	152—172	161	134—148	143	163—175	169
Orbit diameter	23—27	25	22—30	26	24—27	25
Interorbital width	68—82	76	68—77	72	65—74	70
Depth of bill	12—18	15	10—16	13	8—10	9
Width of bill	17—20	18	15—20	17	12—16	14
Origin first dorsal to edge of fin	89—106	97	94—121	104	124—141	133
Length of second dorsal base	47—56	54	42—56	49	39—48	44
Length of first anal base	111—136	127	149—174	166	139—163	152
Length of second anal base	45—57	50	45—56	52	36—46	42
Anterior height of first dorsal	133—148	141	145—171	158	177—199	192
Anterior height of second dorsal	32—45	40	33—49	42	43—53	49
Height of first anal	99—124	112	122—146	134	119—125	122
Anterior height of second anal	31—40	34	24—37	32	33—47	37
Length of pectoral	204—234	223	195—223	210	194—215	206
Length of pelvic	108—140	125	133—215	167	124—187	152
Length of second dorsal	105—125	116	98—123	111	97—111	102
Length of second anal	101—122	108	98—118	108	84—100	92
Length of upper caudal lobe	235—272	256	252—300	269	236—255	247
Length of lower caudal lobe	229—254	245	236—289	257	216—234	224
Dorsal spines	33—41	37.6	39—45	41.8	39—43	41.3
Dorsal rays	6—7	6.7	6—7	6.6	6	6
Anal spines	10—14	12.4	14—17	15.5	14—16	15.1
Anal rays	6—7	6.6	6—7	6.7	6	6
Pectoral rays	19—21	20.1	20—22	21.4	19—21	20

populations and their presence is in agreement with the wide, geographic separation existing between the Atlantic and Pacific samples.

Taxonomic Relationships

A comparison of *Makaira ampla* with its Pacific relatives, *M. marlina* and *M. mitsukurii,* shows that despite their resemblance, these species are well characterized and differ from one another in several characters. The three species are compared in Table 3 on the basis of 42 morphometric and five meristic characters. Absolute differences between *M. ampla* and each of the other two species are indicated by solid lines. Average differences are indicated by dotted lines.

Morphometrically, *Makaira ampla* differs from *M. marlina* in 25 proportions of which seven show absolute differences. Of the 18 proportions indicating only average differences, six show very little overlap and could be considered as nearly absolute differences. These characters show that *M. ampla,* compared with *M. marlina,* has the pectoral, pelvic and anal fins inserted more anteriorly, the body more slender, less compressed and less heavy at the shoulders, the head, snout, maxillary and mandible shorter, the first dorsal and first anal fins higher and the first anal base and pelvic fins longer. Meristic differences are only average but well marked and the means indicate that *M. ampla* usually has about four more dorsal spines, three more anal spines and one more pectoral ray than *M. marlina.*

Comparison with *Makaira mitsukurii* shows that *M. ampla* differs morphometrically in 32 proportions of which eleven show absolute differences. Eight of the 21 proportions indicating only average differences show little overlap and could be considered as nearly absolute differences. These characters show that *M. ampla* has all the fins more anteriorly inserted, a much more robust body, longer caudal keels, a much shorter head, snout, maxillary and mandible, the bill thicker at the tip of the mandible, a much lower dorsal fin, a higher anal fin and longer caudal lobes. There are no well marked meristic differences between *M. ampla* and *M. mitsukurii* but the number of dorsal and anal rays is six or seven in *M. ampla* whereas in *M. mitsukurii* it appears to be always six. The means indicate that *M. ampla* has, on the average, about one more pectoral ray than *M. mitsukurii.*

As already described in the preceding section, the lateral line in *Makaira ampla* is inconspicuous, complex and forms a reticulate pattern on the sides of the body. In *M. marlina* and *M. mitsukurii* the

lateral line is visible, simple and runs along the middle of the sides of the body. It is evident in *M. mitsukurii* but difficult to see in *M. marlina* (Nakamura, 1952: 63).

The median, longitudinal ridge in the isthmus described in the preceding section is present and conspicuous in *Makaira ampla* and *M. mitsukurii* but absent in *M. marlina.*

In both *Makaira ampla* and *M. mitsukurii* the pectoral fin is flexible and can easily be folded back, flat against the side of the body without breaking the joint. In *M. marlina,* however, the pectoral fin is rigid and cannot be folded back against the body without breaking the joint, as described in the preceding section. In this species, if the pectoral is gradually forced back against the side of the body, the longitudinal axis of the fin may be made parallel to it just before the joint breaks, but the plane of the fin will always remain perpendicular or nearly so, to the side of the body, not flat against it. If released, the fin will snap erect again.

A comparative study of the shape of the pectoral fin has revealed marked differences among the three species. In *Makaira ampla,* the fin is less falcate and its edges more straight than in *M. marlina,* whereas in *M. mitsukurii* the fin is much broader in the middle than in the other two species with the anterior edge curved and the posterior edge nearly straight.

There is a great deal of resemblance, variation and intergradation in the color pattern of the three species. In *Makaira mitsukurii,* as implied by its common name (striped marlin), the color pattern is characterized by a series of vertical stripes on the sides of the body which are very conspicuous in life (Gregory and Conrad, 1939, pl. 6) and remain clearly visible after death. In *M. ampla,* a much less conspicuous striped pattern sometimes shows in life but nearly disappears after death and may or may not remain faintly visible in some individuals. A similar, even less conspicuous color pattern occurs in *M. marlina,* but in this species a striped pattern very seldom shows in life and never after death except perhaps in some young specimens.

The quantitative and qualitative characters discussed above indicate that these species are well characterized and differentiated from one another and that *Makaira ampla* is intermediate between *M. marlina* and *M. mitsukurii* but more closely related to the latter. The three species are now known to occur together at the same time off Aca-

pulco, Mexico and in the Gulf of Panama (Table 1). According to information obtained locally they have all been taken in those localities every month of the year.

The marlin reported from Acapulco as "silver marlin" (*Makaira mazara tahitiensis*) by LaMonte (1955: 337) are probably blue marlin (*M. ampla*). She states that the specimens " . . . did not have rigid pectorals as far as could be seen . . . It is possible that in the rough handling, which scarred both sides . . . something had broken and the pectoral therefore lay flat." Of the three species of marlin known to the present writer from Acapulco, only the black (*M. marlina*) has rigid pectorals. However, in this species (reported as *M. mazara* by LaMonte, l.c.) the broken joint of the pectoral is clearly seen when the fin is forced against the side of the body as a result of rough handling.

The following key, based on the specimens examined in this study, shows relationships and serves as a means for identification. Proportions are expressed in thousandths of the body length.

1a.-Pectoral fin falcate, rigid, not folding back flat against sides of body without without breaking joint. Median ridge in isthmus absent. First dorsal fin lower, its anterior height 133 to 148, shorter than distance between origins of first dorsal and pectoral fins. First anal base shorter, its length 111 to 136, shorter than distance between origins of first dorsal and pectoral fins. Body deeper anteriorly: Origin of first dorsal to origin of pectoral 170 to 188; origin of first dorsal to origin of pelvic 203 to 226. Head deeper: Origin of pelvic to nape 189 to 199. Dorsal spines 33 to 41, usually 37 to 40. Anal spines 10 to 14, usually 12 or 13. Vertical stripes on sides of body usually absent, very faint when present.
Makaira marlina

1b.-Pectoral fin not falcate, flexible, folding back flat against sides of body without breaking joint. Median ridge in isthmus present and conspicuous. First dorsal fin higher, its anterior height 145 to 199, about equal to or longer than distance between origins of first dorsal and pectoral fins. First anal base longer, its length 139 to 174, about equal to or longer than distance between origins of first dorsal and pectoral fins. Body less deep anteriorly: Origin of first dorsal to origin of pectoral 129 to 166; origin of first dorsal to origin of pelvic 160 to 199. Head less deep: Origin of pelvic to nape 157 to 184. Dorsal spines 39 to 45, usually 41 to 43. Anal spines 14 to 17, usually 15 or 16. Vertical stripes on sides of body present or absent.

2a.-First dorsal fin lower, its anterior height 145 to 171, equal to or shorter, usually shorter than depth of body at origin of first anal; shorter than depth of body at origin of first dorsal. Origin of first dorsal to edge of fin 94 to 121, shorter than height of first anal. First anal fin higher, its height 122 to 146. Caudal lobes longer; the length of the upper 252 to 300; length of the lower 236 to 289;

both caudal lobes longer than head. First predorsal length shorter, 206 to 227. Second predorsal length shorter, 761 to 785. Prepectoral length shorter, 221 to 249. Prepelvic length shorter, 230 to 260. First preanal length shorter, 554 to 579. Second preanal length shorter, 752 to 772. Head shorter, its length 227 to 240. Snout shorter, its length 94 to 105, shorter than height of first anal. Maxillary shorter, its length 134 to 148, shorter than depth of body at origin of first anal; vertical stripes on sides of body usually present but not conspicuous.

Makaira ampla

2b.-First dorsal fin higher, its anterior height 177 to 199, longer than depth of body at origin of first anal; longer than depth of body at origin of first dorsal. Origin of first dorsal to edge of fin 124 to 141, longer than height of first anal. First anal fin lower, its height 119 to 125. Caudal lobes shorter, the length of the upper 236 to 255; length of the lower 216 to 234; both caudal lobes shorter than head. First predorsal length longer, 227 to 259. Second predorsal length longer, 791 to 810. Prepectoral length longer, 256 to 274. Prepelvic length longer, 272 to 292. First preanal length longer, 596 to 616. Second preanal length longer, 781 to 799. Head longer, its length 254 to 273. Snout longer, its length 125 to 138, longer than height of first anal. Maxillary longer, its length 163 to 175, longer than depth of body at origin of first anal; vertical stripes on sides of body always present and conspicuous.

Makaira mitsukurii

Diagnostic features such as color pattern, body form, pectoral fin shape, height of first dorsal and anal fin, length of snout, maxillary and head, and other characteristics, combine to give each species a distinctive facies or visual diagnosis which enables identification on sight.

Taxonomic conclusions based solely on drawings or photographs without previous study of actual specimens are questionable and usually erroneous. However, once the diagnostic characters of the species have been established on the basis of specimens, reliable identifications can be obtained from illustrations providing the critical parts show clearly.

Occurrence in the Pacific Ocean

In addition to Acapulco and the Gulf of Panama, *Makaira ampla* probably occurs throughout the entire tropical and subtropical Pacific. A study of the literature shows that certain nominal species and other records proposed from the central and western Pacific are referable to *M. ampla* as discussed below.

The species reported as *Eumakaira nigra* by Nakamura (1952: 65, 66) and later as *Makaira mazara* by the same author (1954: 37, 38; 1955: 28, 29), from the western Pacific agrees in all characters with

M. ampla. All the critical diagnostic features are included in these publications, especially in the 1955 report in which detailed descriptions and figures are given. A report (1954) edited by the Nankai Regional Fisheries Research Laboratory (in Japanese) gives monthly long-line fishery charts showing the distribution of *Makaira ampla* (recorded as *Eumakaira nigra*) throughout the western Pacific.

The occurrence of *Makaira ampla* off eastern Australia is established by the recently described *Istiompax howardi* Whitley (1954: 58-60, fig. 3) from Bermagui. The diagnosis, description and figure of this nominal species agree in every respect with *Makaira ampla* and clearly separate it from *M. marlina* and *M. mitsukurii*. In comparing the body form of *Istiompax howardi* with the typical body forms of marlins graphed by Gregory and Conrad (1939: 445, fig. 1), Whitley remarks that "It agrees best with their Blue Marlin [*Makaira ampla*], but differs in having anal base farther back in relation to second dorsal base, and in its less tapering thorax." The present study shows that in both the Atlantic and Pacific samples of *M. ampla,* the second anal base is placed on the average somewhat farther forward than the second dorsal base (see second predorsal and second preanal length in Table 2). This character, however, is quite variable and Pacific and Atlantic individuals have been examined in which the second anal base was actually placed farther back than the second dorsal, as shown by Whitley in *Istiompax howardi.*

As to the " . . . less tapering thorax," about the same relationship is shown between the mean body depth at the origin of the first dorsal fin and at the origin of the first anal in the Atlantic and Pacific samples (Table 2) as the corresponding measurements given by Whitley for *Istiompax howardi.* The depth of the body at the origin of the first anal fin is also very variable and whereas in some individuals the body is markedly tapering, in others it is not.

A photograph of the holotype of *Istiompax howardi* (Fig. 1) has been made available by its collector, Col. John K. Howard. It clearly shows the critical diagnostic characters of *Makaira ampla* as established in the present paper.

Photographs of a 500 pound marlin, taken in the Bay of Islands and clearly showing all critical diagnostic features, indicate that *Makaira ampla* also occurs off northern New Zealand. The photographs were obtained by Col. John K. Howard from a local charterboatman, who stated that the pectoral fins were flexible.

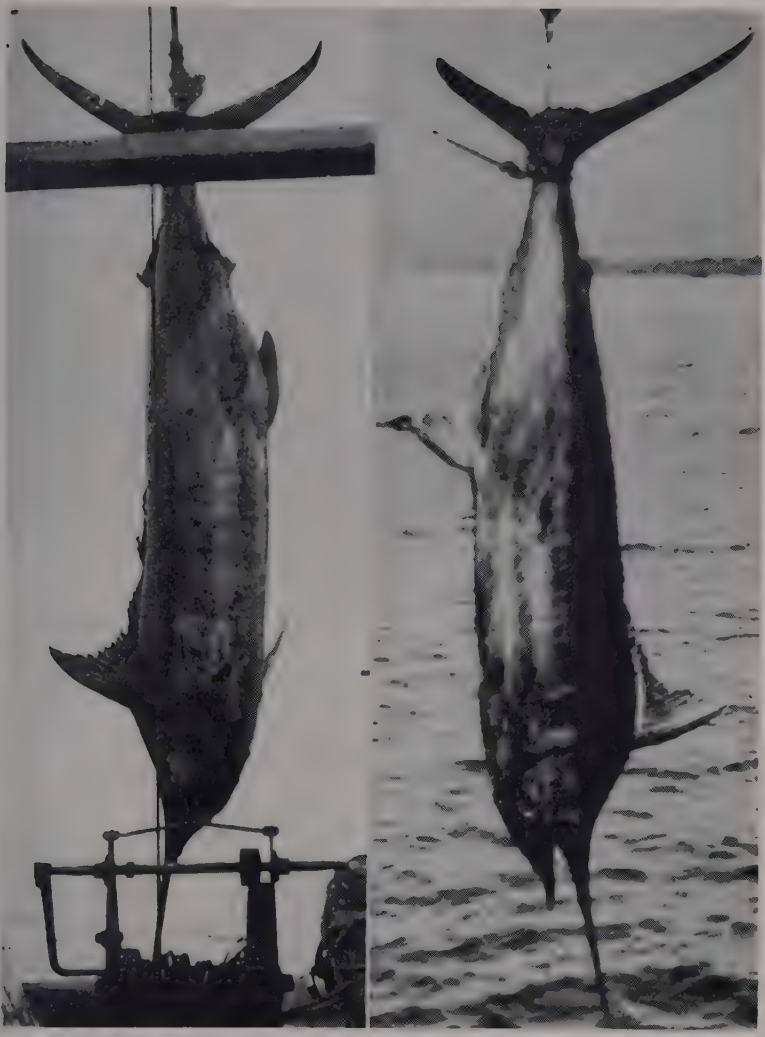

FIGURE 1 (left).—Holotype of *Istiompax howardi* Whitley, 133 inches in total length and 402 pounds in weight. Captured by Colonel John K. Howard, off Bermagui, New South Wales, Australia, in early March, 1953. Photograph courtesy of Col. Howard.

FIGURE 2 (right).—Specimen of *Makaira ampla* Poey, 397 pounds in weight, captured by Anne Thomas in Magdalena Bay, 150 miles north of Cape San Lucas, Baja California, Mexico, on December 21, 1950. Photograph courtesy of Mr. George C. Thomas, III.

The occurrence of *Makaira ampla* in the central Pacific has been ascertained from a careful study of photographs published in the Sportmen's Guide to Outdoors-Hawaii (Biehl, 1953). Of the 38 photographs of marlin shown, 24 can be identified as *Makaira ampla,* especially those on pages 7, 24, 30 (upper left), 31 (left), 44 (left), 45, 46, 47, and 48 (lower left).

In the eastern Pacific, *Makaira ampla* apparently occurs at least as far north as southern Baja California, Mexico, as indicated by a photograph of a specimen 397 pounds in weight (Fig. 2). The fish was taken in Magdalena Bay, 150 miles north of Cape San Lucas by Miss Anne Thomas, on December 21, 1950. The photograph kindly made available for study by Mr. George C. Thomas III of Chatsworth, California, bears the statement: "Pectorals not stiff; had faint stripes."

As already discussed in the preceding section, diagnostic characters combine to give each species of marlin a distinctive facies enabling identification from good photographs.

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A PATTERN OF COASTAL CIRCULATION INFERRED FROM SYNOPTIC SALINITY DATA[1]

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ABSTRACT

A synoptic operation was performed during the forenoon and noon hours on December 4, 1954 when 28 vessels occupied 250 limited hydrographic stations off the west coast of Florida. The salinity distributions are shown for the surface and for 40 feet. The pattern of coastal circulation is referred to the cyclonic eddy off the Florida west coast. Two major indrafts of high salinity water toward the shoreline are found. The mechanics of this phenomenon, and also the permanency of the observed pattern are discussed.

INTRODUCTION

The area under discussion, off the west coast of Florida (see Figures 1 and 2), is characterized by a broad continental shelf sloping gently from the coast to the 100 fathom contour which lies roughly 130 miles off the coast. There are no deep submarine canyons to interrupt this shelf. The coastline consists mainly of numerous barrier islands, except just north of the 27th parallel. Major river systems of the area drain their waters into Tampa Bay and Charlotte Harbor. The westward drainage of Lake Okeechobee through the Caloosahatchee River is controlled, and normally is relatively limited.

For practical reasons, this study was limited to the area between 26°15′ N and 27°35′ N and between the coastline and 50 nautical miles offshore. At that distance from the shore, the depths are approximately 45 fathoms.

This report is based on the results of a large-scale synoptic study of the hydrographic conditions off the west coast of Florida. The field operations were performed as a part of the Red Tide Research for the Florida State Board of Conservation, and were made possible through the cooperation of personnel of the Board of Conservation, the St. Petersburg Office of the U. S. Coast Guard, the U. S. Power Squadrons of the west coast, and many other organized and unorganized citizens of the west coast of Florida, who volunteered their aid, including the Gulf Coast Coordinating Committee. Clarence A. Carpenter, of the Marine Laboratory of the University of Miami, acted as liaison for the different agencies involved.

[1]Contribution No. 154 from the Marine Laboratory, University of Miami.

General Hydrographic Features of the Area of Study

In this area, the isohalines run more or less parallel to the coastline. The water movements are characterized by the Florida west coast cyclonic eddy, the northern end of which is located roughly off Tampa and the outer edge of which extends roughly to the 100 fathom contour.

Chew (1955) has introduced the following names for the different water masses which we shall consider in this report:

(1) "Loop current water mass" which has its source in the warm, saline water flowing north through the Yucatan Channel into the Gulf of Mexico before it returns south to join the Florida current.

(2) "Florida Bay water mass" which has its source in Florida Bay and the shoal regions north of the Florida Keys.

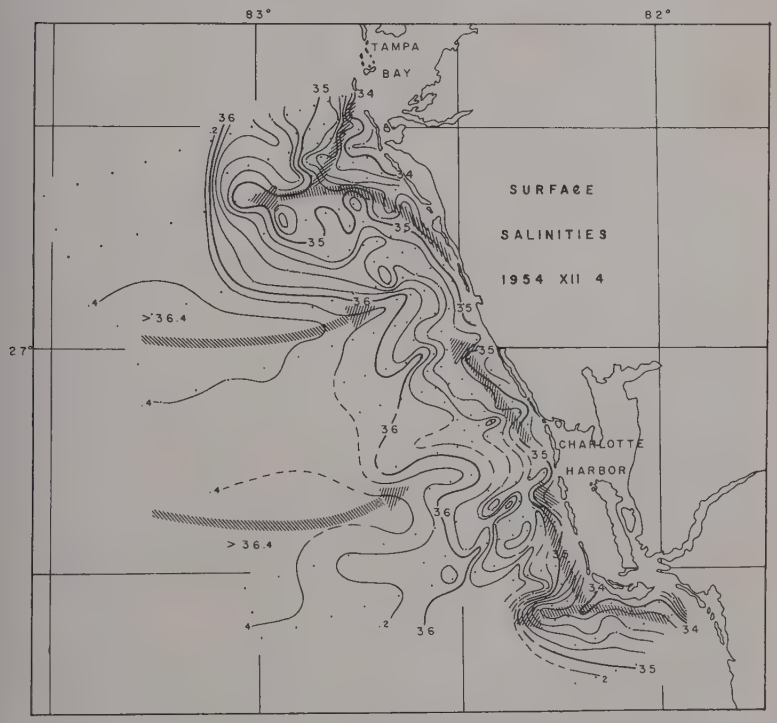

Figure 1.

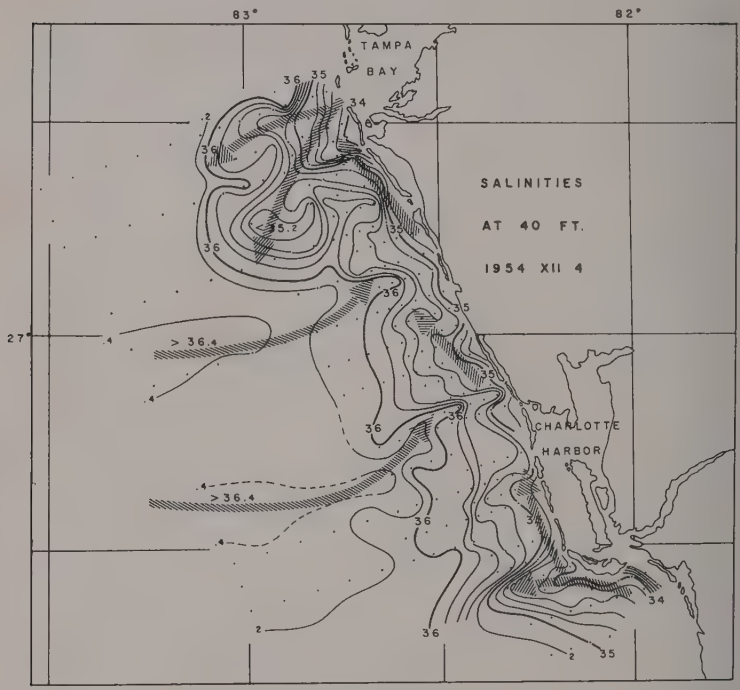

FIGURE 2.

(3) "Florida west coast estuarine water" which has as its primary sources the estuary of the Apalachicola River in the north, and those of the Suwannee River, Withlacoochee River, Tampa Bay, Charlotte Harbor and San Carlos Bay in the east. For this discussion, it seems logical to divide this water mass into two separate subspecies:

(3a) "Florida north west coast estuarine water" and

(3b) "Florida south west coast estuarine water." We can consider the line of demarcation of their sources to be just north of Tampa Bay.

PRESENTATION OF CERTAIN FEATURES OF THE RED TIDE OUTBREAKS

Red Tide is the popular name given to a peculiar discoloration of sea water caused by a microscopic organism. (Ingle, 1955). Many

conflicting theories as to the nature and cause of the Red Tide of Florida have been presented. In January 1947 (Davis, 1947), the organism which is considered to be the immediate cause was isolated. The color and slimy consistency of the water was found to be due, at least in part, to the presence of *Gymnodinium brevis,* a previously undescribed microorganism.

The highest concentrations of *G. brevis* have been found in the passes and close to the shore. In addition, it is almost certain that the spores of *G. brevis* must rest in the same region. Biologically, therefore, the Red Tide must be a littoral problem. However, several observed facts show that the hydrographic conditions off shore are of great importance in understanding the Red Tide. Some of these facts are mentioned below.

The observed outbreaks of Red Tide at beaches generally show a sequence of south to north movement. Thus Gunter (1948) reported: "The Red Tide mortality moved northward and shoreward . . ." Also, Feinstein (1955) reports: "The divisions (of areas of study) shown here were chosen because they emphasize the apparent movement (of the outbreaks) from south to north with the current. The diagram seems to show that most of the outbreaks originate in the southernmost area and proceed north, while others originate farther north; perhaps in the passes." This statement, however, refers only to the outbreaks observed along the beaches.

The Florida Red Tide outbreaks rarely reach the area north of Tarpon Springs, showing that certain hydrographic factors which exist around the area north of Tampa Bay must build a northern barrier for the Red Tide.

As shown by unpublished observations of the Marine Laboratory and others, patches of water with relatively high concentrations of *G. brevis* are occasionally found offshore. Observations during the Red Tide bloom of 1946-1947 (Chew, 1955) showed that patches of dead fish some several to tens of square miles in area were of frequent occurrence. Thus Gunter (1948) wrote: ". . . the Captain of a small freighter . . . sailed through dead fishes from Dry Tortugas to Ft. Myers . . . the disturbance was many miles farther off shore at the southern end of the Florida peninsula than at its northern limits." He also noted that the surface of the ocean north of the Florida Keys was reported to be covered with dead fish. During the briefer outbreak of Red Tide in 1952, the St. Petersburg Times reported on November 12, 1952: "Millions of dead fish from Dry Tortugas to

Ft. Myers . . ." During the Red Tide bloom in 1954, a Coast Guard seaplane (Chew, 1955), summoned by the Gulf Coast Coordinating Committee (a group of citizens organized to aid in the Red Tide work) on July 24, found a large, but thin patch of dead fish some 15-30 miles off shore, measuring several miles wide and upward to many times that long.

Florida West Coast Cyclonic Eddy

There seems to be no doubt of the existence of a permanent cyclonic (counter-clockwise) eddy off the lower west coast of Florida. The monthly charts of the Central American Waters published by the Hydrographic Office (H. O. Misc. 10690 series), although based on units of one degree squares, indicate the permanency of this eddy quite clearly. The same eddy was referred to by Hela (1955) using geomagnetic electrokinetograph measurements made in November 1954 as a basis. Also, Chew (1955, 1955b) has given clear-cut additional evidence to the existence of the eddy on the basis of studies of salinity distribution and the thickness of the isothermal layer.

Synoptic Study

The operation was performed during the forenoon and noon hours of December 4, 1954, when 28 vessels occupied 250 limited hydrographic stations during a period of a few hours. (Dots on Figures 1 and 2 show station locations.) Water samples were taken at the surface, and at a depth of 40 feet at all stations. Some of the samples were analyzed for natural radioactivity, with negative results. At a limited number of stations, water samples were taken from which University of Florida scientists, under the direction of Dr. James Lackey, later determined numbers of *G. brevis* present.

Although almost negligible, two possible sources of error must be noted. First, some of the vessels were not able to determine station locations with complete accuracy while occupying stations. However, the sea was almost calm during the entire operation, so that these errors are rather limited. In every case the main features of the salinity distribution must be real, and not due to errors of location. Also, it was not possible to store all samples properly immediately after taking them. Nevertheless, comparison of Figures 1 and 2 shows readily that the possible effect of this error can be discounted. The chlorinities were determined by the normal method of careful titration with silver nitrate.

Although the "permanent" water circulation in a relatively shallow coastal area may be determined directly from actual current measurement, its usefulness is often limited, for two reasons:

(1) Knowledge of mean (average) motions is needed for the Red Tide studies. Tidal oscillations usually complicate the current measurements too much to make them practical. These measurements would actually show both the tidal currents and the mean motion as a resulting current over longer periods. Thus, by obtaining a long series of current measurements, the knowledge of mean motion certainly can be found. The amount of labor involved makes this approach impractical.

(2) In this special area, where the tidal oscillations are rather limited, a more serious drawback is due to changing drift currents, caused by local winds.

Since a result of the total motion of the water is to shift water masses from one place to another, the mean motion can be determined indirectly from the distribution of salinity and/or temperature. Although it was not possible to include temperature observations in this operation, it was felt that in this case, with relatively large variations of the salinity off shore, the salinity alone can adequately indicate water movements. This is a reasonable assumption for the area of interest, as the sources of the major water masses are known. Since it is equally reasonable to state that the geostrophic state cannot prevail in this area, water may cross the isohalines, and hence the salinity of water can be used as a tracer for its movements.

The most important aspect of the present study is the synoptic quality of the acquired salinity data. This is believed to be the first time that an area of this magnitude has been covered almost simultaneously with any kind of hydrographic observations. It is felt the results show that similar efforts in any coastal area could be very profitable in increasing our understanding of the details of circulation.

Results

Figures 1 and 2 show that, in general, there was not too much difference between the salinity distribution at the surface, and that at 40 feet (12 meters). The main difference appears southwest of Tampa Bay, where the surface water is less saline than the deeper water, thus indicating the shallowness of the layer of coastal water in this area.

There must be a general (northerly) water movement along the coast, since no major changes in salinity occur coastwise, except southwest of Tampa Bay, and, possibly, west of San Carlos Bay. However, the velocity of the northerly water movement cannot be the same along the whole coastal section, since the isohalines are not altogether parallel to the coastline but meander rather abruptly. At least one, and probably two, clear-cut compensatory indrafts of high salinity water are directed to the coastline; one toward Stump Pass, roughly, north of Charlotte Harbor, and the other toward Venice, roughly, south of Tampa Bay. In the region of these indrafts, water of high salinity (over 36 parts per thousand) is found less than 15 miles off shore, while southwest of Tampa Bay, the corresponding distance is almost 30 miles off shore. Apparently the "Loop current water mass," partly diluted with estuarine waters, penetrated the coastal region in form of these indrafts, while the area immediately close to the coastline is characterized by the "Florida south west coast estuarine water" in the south, and also by the "Florida north west coast estuarine water" just off Tampa Bay.

A communication from Mr. Frank Chew suggests that data obtained by the Marine Laboratory more recently may indicate that the observed high saline water is part of a saline tongue stemming from Florida Bay and entering the cyclonic circulation at its shoreward stage. Field samples from the area immediately north to northwest of Key West, collected on January 11, 1956, show salinity as high as 37.22‰ and none below 36.40‰. Apparently the high summer evaporation in the Florida Bay is continued into the winter months. In certain aspects this is similar to that over the eastern part of the Mediterranean Sea (Sverdrup, 1955: 147).

A close study of the isohalines reveals several other interesting details. The rather abrupt salinity gradient some 20 miles southwest of Tampa Bay is of importance. Also, several details seem to indicate the presence of water patches having a salinity different from that of the immediately surrounding water. The presence of these patches is to be expected in view of the occasional discrete patches of *G. brevis* off shore.

Interpretation of Results

There are three facts, shown by this study, which must be discussed in the interpretation of results:

(1) The existence of the cyclonic eddy, with reference to previous studies.

(2) The existence and significance of the major indrafts.

(3) The existence and significance of the separate water patches.

(1) The author believes that it is most likely that Chew's (1955) explanation of the primary origin of the cyclonic eddy (in the sense of Rossby's jet [Rossby, 1936]) is correct. Chew eliminated the other explanations (wind-driven circulation and thermohaline circulation) as less probable or impossible, and concluded that "In this model a steady stream ('Loop current') moving through a resting fluid entrains water (in this case 'Florida west coast estuarine water') from the environs into the stream." The results of this study do not contradict this explanation.

(2) Miller (1952) has found phenomena similar to the indrafts in his study of the coastal circulation between Block Island and Cape Hatteras. However, these indrafts have not been observed off the Florida west coast before this study. Therefore, two major questions must be answered:

(a) Are these indrafts permanent, or, at least, semipermanent?

(b) Are the indrafts physically impossible?

It is evident that the permanency of the detailed pattern is doubtful. Further studies are needed so that the true existence of the main features other than the cyclonic eddy can be verified. There are three factors which will cause basic changes in the water movements of this area: (i) fluctuations in the Florida current and, more locally, in the "Loop current"; (ii) local winds will at least shift the location of different features to a certain extent; (iii) variations in the runoff of rivers draining into the area will cause at least minor changes. In spite of these three factors, the indrafts are probably permanent in character. The high salinity of the indraft waters, amidst less saline water presupposes constant advection. If this were not so, the continuous diluting effect of the drainage from the shoreline would cause the indrafts to vanish rather quickly.

Apparently the indrafts are physically possible, especially if we consider the vorticity conditions (cf. Chew, 1955). Starting at the northwestern edge of the Florida west coast cyclonic eddy, the "Florida west coast estuarine waters" are entrained toward the "Loop current" and finally into the SSE bound "Loop current," thus gaining an increasing amount of positive vorticity due to the southerly component

of the movement, and due to the increasing depth. Part of these waters, as a result of their positive vorticity, will continue their counter-clockwise course toward the shoreline, i.e., roughly in the direction ENE. The positive vorticity will be depleted rather quickly, due both to the decreasing depths and to the northerly component of the movement. It does not seem to be surprising, therefore, that the original cyclonic curvature of the indrafts disappears, and the advection of high salinity water continues almost perpendicularly to the shoreline. Physically the existence of two or even more indrafts, instead of only one major "southern end of the cyclonic eddy," is possible. We may conclude that the indrafts not only seem to be physically possible, but also seem to be real.

The significance of the indrafts is evident. If and when it is shown, preferably by rapid north-south hydrographic sections, that the indrafts are at least semipermanent, it will be possible to refer the shoreward movement of the Red Tide debris to them. In this connection, it is most interesting to note the regional distribution of records of "Red Tide outbreaks," which generally manifest themselves as littering of beaches or similar "secondary phenomena" (since the studies, of necessity, are based primarily on reports of shore observations). Feinstein (1955), in her analysis, divided the Red Tide coast of Florida into seven arbitrary areas. It is relatively clear that the Red Tide phenomena, most frequently observed by laymen and thus secondary in the above sense, are most common in her areas III (Passage Key Inlet south to Midnight Pass) and VI (La Costa Island south to Sanibel Island). It is again interesting to note that the two major indrafts found in this study roughly correspond to the above areas III and VI.

(3) The existence and significance of the separate water patches, especially of less saline, coastal water patches amidst more saline water, are probably of most interest because of the relatively high concentration of certain littoral effects (in particular, *G. brevis*) which are occasionally found off shore. However, further details cannot be deduced from these data alone.

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